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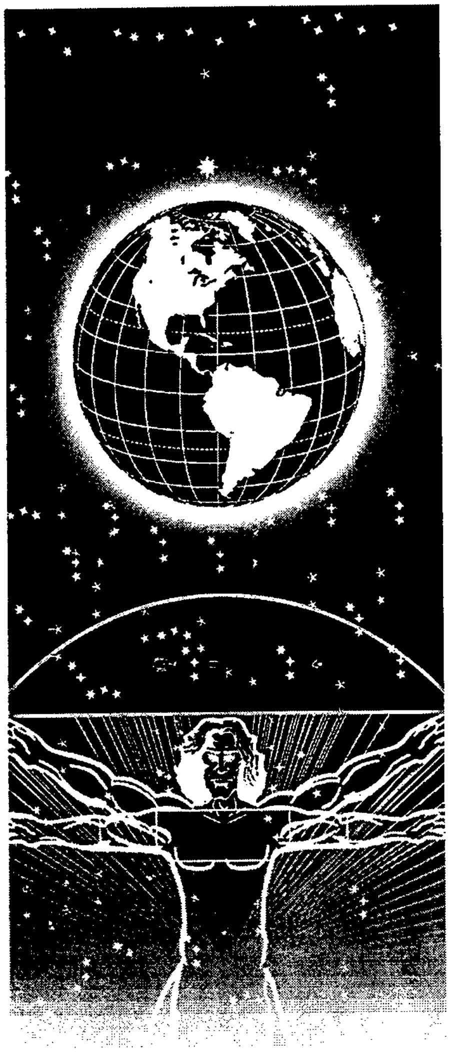

UNITED STATES AIR FORCE RESEARCH LABORATORY

EVALUATION OF ABOVE REAL-TIME TRAINING AND SELF-INSTRUCTIONAL STRATEGIES FOR AIRMANSHIP TASKS ON A FLIGHT SIMULATOR

Syed Firasat Ali

Aerospace Science Engineering Department
Tuskegee University
Tuskegee, AL 36088

Dutch Guckenberger

SDS International
2011 Crystal Drive
Arlington, VA 22202

Marcia Rossi
Mayard Williams

Tuskegee University
Aerospace Science Engineering Department
Tuskegee, AL 36088

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AIR FORCE RESEARCH LABORATORY
HUMAN EFFECTIVENESS DIRECTORATE
WARFIGHTER TRAINING RESEARCH DIVISION
6030 South Kent St., Bldg 561
Mesa AZ 85212-6061

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The Office of Public Affairs has reviewed this report, and it is releasable to the National Technical Information Service, where it will be available to the general public, including foreign nationals.

This report has been reviewed and is approved for publication.

PETER CRANE
Project Scientist

DEE H. ANDREWS
Technical Director

JERALD L. STRAW, Colonel, USAF
Chief, Warfighter Training Research Division

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6. AUTHORS
Syed Firasat Ali
Dutch Guckenberger
Marcia Rossi
Mayard Williams

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Aerospace Engineering Dept, Tuskegee University, Tuskegee AL 36088

SDS International, 2011 Crystal Drive, Arlington VA 22202

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14. ABSTRACT
Research on a flight simulator was conducted to (a) develop and validate performance measures for the basic tasks of flying a Predator airplane, (b) evaluate above real-time training (ARTT) as a training strategy, and (c) evaluate the use of in-flight and post-flight feedbacks for self instruction. Several three-minute flights by student pilots on a simulator were graded simultaneously by a certified flight instructor and a computer. Computer grades were based on prescribed tolerances in different parameters for A, B, C, and D grades. For straight-and-level flights, acceptable correlation coefficients were found between instructor's grades and computer grades. For students trained in real-time training (RTT) with in-flight and post-flight feedback for self instruction, an increase in performance with the amount of training was visible until completion of training. For the group trained in RTT without any feedback, the visible increase in performance was limited to the first few training flights. Comparison of ARTT and RTT required further investigation. For straight-and-level flights and for more flying maneuvers, further research is proposed.

15. SUBJECT TERMS
Above real-time training, ARTT, Flight performance measures, Flight simulator training, Flight simulators, Historically Black Colleges and Universities, HSCU, Real-time training, RTT, Self instruction, Time compressed training

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PREFACE

The work was sponsored by the US Air Force Grant through the Air Force Research Laboratory under Agreement Number F41624-98-1-0005. The equipment was acquired under the NASA Grants NAG3 133 and NAG4 169 through Dryden Flight Research Center.

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Edward Scott Barland, a certified flight instructor, provided consulting support including evaluation of performance of volunteer trainees. Matt Archer of SDS International remained available as Dutch Guckenberger's co-worker to address the software requirements. Several Tuskegee University Students contributed in the research; special mention may be made of Dennis Ezell, Jason Williams, Abhilesh Loomba, Kevin Dukes, Martin Hayes, and Taneshia Boyd. We would like to extend their thanks to all the contributors., and we are pleased to acknowledge expert advice of Peter Crane who had been much more supportive of the work than a Technical Monitor in his official capacity would normally do.

CHAPTER 1: FLIGHT AND SIMULATION TRAINING

1.1 Development of Simulator Training

In the early part of the twentieth century, airplanes became more abundant and flying them became more challenging, due to learning to fly by trial and error. This method usually resulted in either damaged aircraft's or a trainee being killed during practices. The need for training without the use of the operational equipment was in high demand. This is where the initiative to capitalize on the technology of flight training came about. This was done by building machines that would simulate flying an aircraft. It was necessary to provide a realistic environment to be sure that the training received in a simulator would transfer the knowledge needed to operating a real vehicle.

In the 1950's simulators became increasingly important because of the complexity of the aircraft and the corresponding increase in the cost of training a pilot. This led to more realistic simulators to produce higher levels of transfer in training them. Because of limitations of engineering knowledge, these simulators were more accurate in cockpit design than in flight characteristics. As the need was recognized, the level of transfer became critical in going from the simulation world to the operational. With the advent of digital computers, more accurate models with key considerations to flight dynamics and aircraft systems became possible. Within a short time, simulators were used in every aspect of flight training and highly regarded by the Federal Aviation Administration (FAA) and US military services as efficient training for pilots.

One might wonder how effective training can be without a realistic simulator, but in actuality training for most tasks in a low realism simulator has enabled pilots to perform as well in aircrafts as pilots that were trained in a high realism simulator or in actual aircrafts (Prophet & Boyd, 1970, adapted from Caro, 1988). The key lies in the cues that pilots depend on when it is necessary to perform a given task. They depend on cues to assess the condition and status of the aircraft and to initiate actions or guide them when on to perform or not perform a desired action. A skilled pilot's performance is highly dependent on making the desired responses to cues. Important considerations in training and using cues are how efficiently a pilot can recognize a cue and then make the appropriate maneuver or response to that cue. The pilot will need to learn to discriminate between two signals that may be physically identical but will require two different responses for each signal. As the task becomes harder, the ability to discriminate becomes just as hard, where the discrimination could possibly depend on very small differences in signal. Overall, the simulator and its components all work for one common goal: that is, to help develop efficient pilot training, without any loss of skills and knowledge when transferred into an operational machine (Caro, 1988).

1.2 Above Real Time Training

Above real-time training (ARTT) is the training acquired on a real time simulator when it is modified to present events faster than normal. The works of Kolf (1973) and Hoey (1976) suggested that above real-time training of pilots would lead to significant increase in the effectiveness of flight training although it results in reduced simulator fidelity. Kolf (1973) noted, "regardless of type or amount of pre-flight simulator training accomplished by the pilot,

the actual flight appears to take place at a much faster time frame than real time." Kolf (1973) modified the M2-F3 Lifting Body simulator to increase the pace of events 1.5 times their pace in real time. Three pilots who had already flown the M2-F3 expressed that the modified simulator felt exactly like the aircraft. Hoey (1976) reports that the mental state of test pilots operating remotely piloted vehicles can be approximately simulated without stressful conditions by increasing the simulated rate of time passage.

In their extensive work on exploring the benefits of ARTT, Guckenberger et al. (1997) placed the objectives of NASA Dryden Flight Research Center and Air Force Human System Center's Technical Planning Integrated Product Team (HSC, TPIPT) in perspective. They proposed that the Air Force flight training may derive the following benefits from ARTT: increased task performance, increased trainee retention of skills, increased situation awareness, decreased real time work load, decreased real time stress, increased rate of skill acquisition, reduced simulator and aircraft training time, and more effective emergency procedures training. Crane and Guckenberger (1997) have reported that pilots trained using ARTT performed emergency procedures and defeated bandit aircraft significantly faster than pilots trained in real time.

Rossi et al (1999) trained university students on a gunnery task to compare RTT and ARTT at 1.5 times real time. The students trained in ARTT performed on test trials as well as students trained in RTT, although the ones trained in ARTT spent less clock time. During the training, however, the performance of students in ARTT was depressed compared to students trained in RT. Rossi et al (1999) hypothesized that the use of ARTT as top-off training after RTT would result in more effective training. Williams (1999) found that ARTT as top-off training after RTT offers better training in comparison to ARTT alone or RTT alone.

The present effort addressed the use of ARTT for training pilots to perform basic flight maneuvers. The performance during the learning of these skills should correspond with Fitts and Posner's (1967) model that recognizes three basic stages of skill acquisition: they are cognitive, associative and autonomous. For a relatively complex task, introducing ARTT may be more effective at the autonomous stage or used as top-off training. Because the task may be more complex, it should follow Schneider's (adapted from Guckenberger et al 1997) guidelines for training complex skills, which are the following:

- Design training to allow many trials of critical skills.
- Maintain active participation by minimizing passive observation of the task.
- Maintain high motivation throughout the training period.
- Train under mild speed stress.
- Train strategies that minimize operator workload.
- Train time-sharing skills for dealing with high-workload environments.

The mild speed stress is expected to be a distinct feature of ARTT, whereas most of the other features desired in Schneider's guidelines are also addressed in ARTT. For a less complex task, for example flying straight and level, ARTT may offer the benefit of improved time efficiency of training if it is introduced at the associative stage. For a relatively complex task, for example turning or climbing in a flight, introducing ARTT may be more effective at the

autonomous stage. Alternatively, for complex tasks, ARTT may be used a stop-off training after RTT. The present effort has included the study of ARTT with 1.5 times real time used for top-off training.

1.3 Self-Instructional Techniques

Many organizations have implemented training programs that will enhance the overall development of the pilot. These programs are organized to make sure the precise delivery of training is adequate for each pilot. Implementing self-instructions allows the pilot to obtain the necessary knowledge needed to perform maneuvers and stick controls in relation to the simulator by reading a script or looking at a video.

With the increase in computer-based learning and distance learning, self-instructional strategies are becoming more widely used. The present effort involved an attempt to minimize the amount of flight instructor time required during simulation training and to allow student pilots to figure out errors in their performance by themselves. Thus, mechanisms for the student pilot were needed to:

- Provide initial instruction to the pilot.
- Provide feedback during and after a flight.

For initial instruction, a video was developed to familiarize participants with the equipment and the four basic flight maneuvers to be taught (See Appendix I for video script that was used for all participants in the program).

1.4 Feedback System

The present research examined the use of in-flight automated feedback and post-flight automated feedback. The in-flight feedback was provided in the form of audio cues consisting of a beeping signal. These were initiated when either the pilot's altitude or heading was out of the prescribed 'D' grade tolerance. The beeping signal remained until the parameter returned within the tolerance level. The post-flight feedback was provided by showing a set of strip charts to the student immediately upon completion of a flight. The strip charts provided a graphical comparison of prescribed tolerances with the parameter values reached in a student's flight.

1.4.1 Implementing the Audio Cue

In a Microsoft Excel scoring file, the first column provides the time instants in seconds. For 'A' grade performance by a trainee, the required values and allowed tolerances of 3 or more flight parameters are provided against each time instant. The tolerances for 'B', 'C,' and 'D' grades are respectively two times, three times, and four times the tolerance for the A grade. When a parameter is beyond 'D' grade performance, it is considered out of bounds. The code performs grading of a trainee's flight using the scoring file as the criterion as shown in Appendix II, Tables 1-4.

The Visual Basic code performs well for the time instants expressed in seconds when the fractions or decimal fractions of a second are not included in the scoring table. Because of this, the time instants were implemented as 2.0, 3.0, 4.0....178.0, 179.0 second integer time values.

1.4.2 Out-of-Bounds Audio Signal

This signal is issued at any such monitored time instant when the altitude or heading is beyond grade 'D' limits. It is a beeping tone of 500 Hz frequency for a duration until heading or altitude is corrected. To determine the out-of-bound signal, only two parameters, altitude (H) and heading (PSI), are monitored. The scoring tables or parametric tables have desired altitudes and headings at one-second intervals from 1.0 to 180.0 seconds. To determine out-of-bound signals, 't' represents 3.0, 6.0, 9.0, ...180.0 seconds, the time instants 2.9, 5.9, 8.9, ...179.9 are omitted. The following is an example of how the simulator monitored the altitude and heading for out-of-bound audio cues:

A1. Monitor Alt(t) = altitude at time t second in the flight.
A2. Monitor Heading(t) = heading at time t second in the flight.
A3. Pick the value of H(t) = altitude given in the scoring table at time t second.
A4. If H(t) = ng, then go to A10, otherwise move on to A5.
A5. Pick the value of H_tol(t) = tolerance in altitude, given in scoring table allowed for 'A' grade or 4-point performance.
A6. HMAX(t) = H(t) + 4 * H_tol(t)
A7. HMIN(t) = H(t) – 4 * H_tol(t)
A8. If Alt(t) > HMAX(t), then issue the out-of-bound audio cue and go to A10, otherwise move on to A9.
A9. If Alt(t) < HMIN(t), then issue the out-of-bound audio cue and move on to A10, otherwise do not issue out-of-bound audio cue but move on to A10.
A10. Pick the value of PSI(t) = heading given in the scoring table at time t second.
A11. If PSI(t) = ng, go to A1 for another time interval, otherwise move on to A12.
A12. Pick the value of PSI_tol(t) = tolerance in heading, given in scoring table, allowed for 'A' grade or 4-point performance.
A13. PSIMAX(t) = PSI(t) + 4 * PSI_tol(t)
A14. PSIMIN(t) = PSI(t) – 4 * PSI_tol(t)
A15. If Heading(t) > PSIMAX(t), then issue the out-of-bound audio cue and go to A1 for another time instant, otherwise move on to A16.
A16. If Heading(t) < PSIMIN(t), then issue the out-of-bound audio cue and go to A1 for another time instant; otherwise, do not issue out-of-bound audio cue and go to A1 for another time instant.

Go to A1 for another time instant implies: Repeat the procedure to monitor the altitude and heading for out-of-bound audio cues at the next time instant. This is done up to a time instant preceding 180 seconds, typically up to t = 177 seconds.

1.4.3 Trending Out-of-Bounds Audio Signal

Trending out-of-bounds is another method that can be used to enhance the automatic feedback system. The first audio signal or the advance warning audio signal should be issued immediately whenever the time derivative of any tracked parameter is either greater than its maximum allowed value or less than its minimum allowed value.

Related Math

DT = A response time in seconds taken by pilot to perceive and control a deviation of a flight variable; it includes response time of the control mechanism.

UMAX = Maximum value of a variable allowed for a 'D' grade performance.

UMIN = Minimum value of a variable allowed for a 'D' grade performance.

U(t) = Value of a variable at time t.

Δt = Increment in time used to calculate the time derivative of a variable.

DDT(t) = Time derivative of a variable at time t.

DDTMAX(t) = The value of time derivative at t, above which an audio signal is required.

DDTMIN(t) = The value of time derivative at t, below which an audio signal is required.

The derivative monitoring or anticipatory monitoring of U(t) is determined when $UMIN < U(t) < UMAX$ and $UMIN < U(t-\Delta t) < UMAX$ at time t.

The parameter U(t) is monitored continuously, or at every one tenth of a second, or at every one third of a second; at the discretion of the programmer.

The following computations are performed:

$$DDTMAX(t) = (UMAX - U(t)) / DT$$
$$DDTMIN(t) = (UMIN - U(t)) / DT$$
$$DDT(t) = (U(t) - U(t-\Delta t)) / \Delta t$$

Audio signal is required whenever
$DDT(t) > DDTMAX(t)$ or $DDT(t) < DDTMIN(t)$

Example: Consider altitude monitoring.
Let the altitude be monitored at every one tenth of a second.
Recommend DT = 2 seconds, Δt = 0.1 second
UMAX = 10,200 ft
UMIN = 9,800 ft

Let the real time values of U in a flight be the following:
U(t-Δt) = U at 0.9 second = 10,040 ft.
U(t) = U at 1.0 second = 10,050 ft.

The following conditions are met:
9,800 < 10,050 < 10,200 and 9,800 < 10,040 < 10,200

Therefore, derivative monitoring is needed and the following computations are performed for t = 1 second:
DDTMAX(t) = (10,200 - 10,050)/2 = 75 ft/s; at this rate of climb, the airplane will go above UMAX in 2 seconds.
DDTMIN (t) = (9,800 - 10,050)/2 = -125 ft/s; at this rate of descent, the airplane will go below UMIN in 2 seconds.
DDT(t) = (10,050 – 10,040)/0.1 = 100 ft/s; at this rate of climb, the airplane will go above UMAX in less than 2 seconds.

It is found that DDT(t) > DDTMAX(t) or the climb rate is too rapid, the derivative audio signal is required.
As a second example, let the real time values of U be the following:
U(t-Δt) = U at 1.9 second = 10,097 ft.
U(t) = U at 2.0 second = 10,100 ft

The following conditions are met:
9,800 < 10,097 < 10,200 and 9,800 < 10,100 < 10,200 therefore derivative monitoring is needed and the following computations are performed for t = 2 second.
DDTMAX (t) = (10,200 – 10,100) / 2 = 50 ft/s; at this rate of climb, the airplane will go-above UMAX in 2 seconds.
DDTMIN (t) = (9,800 – 10,100) / 2 = 150 ft/s; at this rate of descent, the airplane will go below UMIN in 2 seconds.
DDT (t) = (10,100 – 10,097) / 0.1 = 30 ft/s; at this rate of climb, the airplane will not go above UMAX or below UMIN in less than 2 seconds.

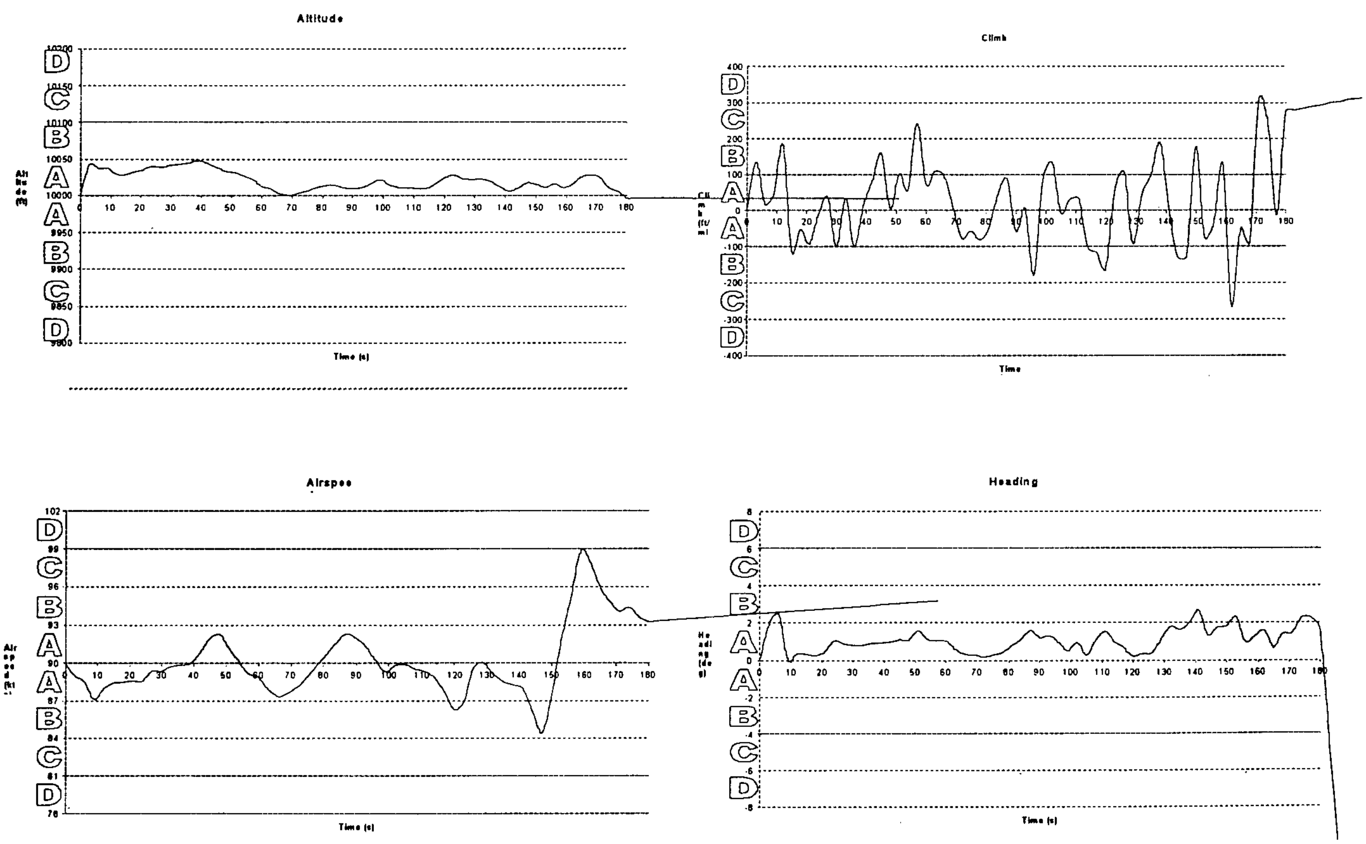
It is found that DDT (t) is not greater than DDTMAX (t) and DDT (t) is not less than DDTMIN (t), therefore the derivative audio signal is not required.

1.5 Strip Charts

In the post-flight feedback program, all tracked parameter values were accumulated during the entire task and overlaid on a display chart of desired parameter values after the task was completed. Figure 1.1 shows the tracked parameter for altitude, heading, rate of climb, and airspeed. The x-axis represents time in seconds and the y-axis represents the range of values for that parameter in its respective units. From this chart, one can visually see the time history of the student's progress until the completion of the flight. The 'A,' 'B,' 'C,' 'D' marks on the chart represent what type of grade the pilot is receiving at that point in the flight.

These four sample charts are actual charts from a student pilot's training session (refer to Appendix II for more charts from a flight). The altitude chart shows that this student flew the entire flight within the maximum tolerance for an 'A' grade. The rate of climb chart shows that the student kept minimum input on the stick, thus resulting in a low rate of climb, which leads to a more consistent altitude. If the pilot did not have control, then the rate of climb chart would show lines that are not uniformly connected, indicating that the pilot was constantly pushing forward or back on the stick to maintain the desired altitude. For the airspeed and heading charts, one can easily notice that the pilot remained within the desired tolerances for an 'A' grade, only leaving that area for a few seconds at a time. One can notice the minimum time taken to correct the deviation once the pilot fell out of the desired path. These charts were available to the pilot after the completion of the flight depending on what program the pilot was placed in. More charts and description on this portion of the program are presented in Chapter 2.

Figure 1.1: Strip Charts for Straight and Level



CHAPTER 2: PERFORMANCE MEASURES

2.1 Proposed Performance Measures

To devise a set of performance measures, due consideration was given to the existing information and suggestions. Private Pilot Practical Test Standards, a publication of the Federal Aviation Administration (FAA), identifies straight and level flight, climb, descent, and turn as the four basic flight maneuvers. For the testing of a trainee on a single engine airplane, the permitted tolerances by the FAA are as follows: altitude ± 200 ft, heading ± 20°, and airspeed ± 10 kts. Vogel (1999) acknowledges that by training a candidate to flawlessly accomplish each of the four basic maneuvers, the flight instructor can then help the trainee combine them into more complex maneuvers that one needs to know to become an accomplished and safe pilot. He suggests awarding of grade points 4, 3, 2, 1, 0 on flying performances within given tolerances for different parameters of flight maneuvers. For example, airspeed tolerance is ± 5 kts for 4 points, ±6 kts for 3 points, ±8 kts for 2 points, and ±10 kts for 1 point. If the airspeed remains outside ±10 kts for 8 seconds or more, then the score is zero, for trending back within ±10 kts within 8 seconds, the score of 1 is restored. To score 4 points the trainee must not remain outside the 4-point tolerance for more than 5 seconds. The scores for a maneuver should be determined after the maneuver is completed by comparing the trainee's performance of the maneuver to a template of the maneuver stored in the computer database.
While studying the effects of time delay between control input and airplane response, Ali (1997) allowed six volunteer pilots on an F-15 simulator to conduct several three-minute flights until the performance of every volunteer reached his or her own asymptotic stage. In their asymptotic stage of performance, three of the six trainees could maintain the altitude within ±20 ft and heading within ±2 degrees in straight and level flights.

After consideration of the FAA standards, Vogel's recommendations and Ali's report, the following tolerances for different parameters were proposed for measuring performance of a trainee in the basic flight maneuvers on a simulator. For 'A' grade or 4 point performance, the tolerance was ±3 kts for airspeed, ±50 ft for altitude, ±100 ft/min for climb or descent, and ±3° for heading in climb or descent segment. The tolerances for 'B', 'C', and 'D' grades, respectively, were two times, three times, and four times the corresponding tolerances for the 'A' grade. For example, airspeed tolerance was ±3 kts for 'A' grade or 4 points, ±6 kts for 'B' grade or 3 points, ±9 kts for 'C' grade or 2 points, and ±12 kts for 'D' grade or 1 point. For automated scoring, however, instead of continuous monitoring of a trainee's flight, the grading of monitored parameters was done at every three-second interval. In other words, the automated scoring was based on discrete data instead of continuous data.

2.2 Automated Scoring

To use the proposed performance measures for grading of a flight, a method of scoring was devised and adopted for automated scoring on a simulator. For describing the method of scoring, considered a hypothetical flight with required airspeed of 90 kts for a 30-second duration (Refer to Table 1 for a detailed evaluation of the flight grading system). In the performed flight, the airspeed stayed between 96 kts and 99 kts from 0 to 12 sec, between 99 kts and 102 kts from 12 to 18 sec, between 102 kts and 110 kts from 18 to 27 sec, and between 99

kts and 102 kts from 27 to 30 sec of the flight. To evaluate the performance, we awarded points based on the proposed performance measures: 'A' grade or 4 points for keeping airspeed within ±3 kts of the required airspeed, and 'B', 'C', and 'D' grades for deviations within ±6 kts, ±9 kts, and ±12 kts respectively. For the hypothetical flight described above, the trainee would earn 'C' grade or 2 points from 0 to 12 sec, 'D' grade or 1 point from 12 to 18 sec, a failing grade or zero points from 18 to 27 sec, and 1 point from 27 to 30 sec. The total of the earned points on airspeed performance of 30 seconds would be (2 x 12) + (1 x 6) + (0 x 9) + (1 x 3) = 33 points. The grade point average would be 33 divided by 30 seconds or 1.1.

Table 2.1 Hypothetical Continuous Scoring of Airspeed During 30 Seconds of Straight and Level Flight

Time	A/S (kts)	Grade / Points	Earned pts.
0-12	96-99	C / 2	(2x12) =24
12-18	99-102	D / 1	(1x6) = 6
18-27	102-110	0	(0x9) = 0
27-30	99-102	D / 1	(1x3) = 3
Grade Point Average (GPA) 33/30 = 1.1			

The method of grading described above was based on continuous monitoring of a flight. For automated scoring, however, the grading was based on discrete data monitoring. The grading of monitored parameters was done at every three-second interval. Consider a trainee's flight represented by Figures 2.1 to 2.4 where all of the figures represent the same flight. For a straight and level flight of 3 minutes or 180- second duration, the trainee was required to fly on a simulator at an altitude of 10,000 ft, heading toward North (360° or 0°) with airspeed of 90 kts. Let us consider the automated real time grading of a 30 second segment of this flight, from 150 to 180 sec, based on the monitoring of four parameters: altitude, climb rate, heading and airspeed. The four parameters would be monitored compared with their required values, and graded simultaneously at the instants of 150 sec, 153, sec, 157 sec, ….., 177 sec, and 180 sec. The grade point average would be the sum of all the awarded scores divided by the total number of scores. Automated grading of the desired 30-second segment of the flight is shown in Table 2.2. The sum of all the awarded scores is 152. The total number of scores is 44.

The GPA for the 30-second segment of the flight is 152/44 = 3.55. A flight segment of any duration or the complete flight of any duration may be graded by automated scoring in the same manner.

Table 2.2 Automated Scoring of a 30-Second Segment of the Trainee's Flight Graphically Shown in Figures 2.1-2.4

Time	Altitude Score	Climb Rate Score	Heading Score	Airspeed Score
150	4	3	4	4
153	4	4	3	4
156	4	4	4	3
159	4	3	4	2
162	4	4	4	2
165	4	3	4	3
168	4	4	4	3
171	4	1	4	3
174	4	2	3	3
177	4	4	3	3
180	4	2	4	3

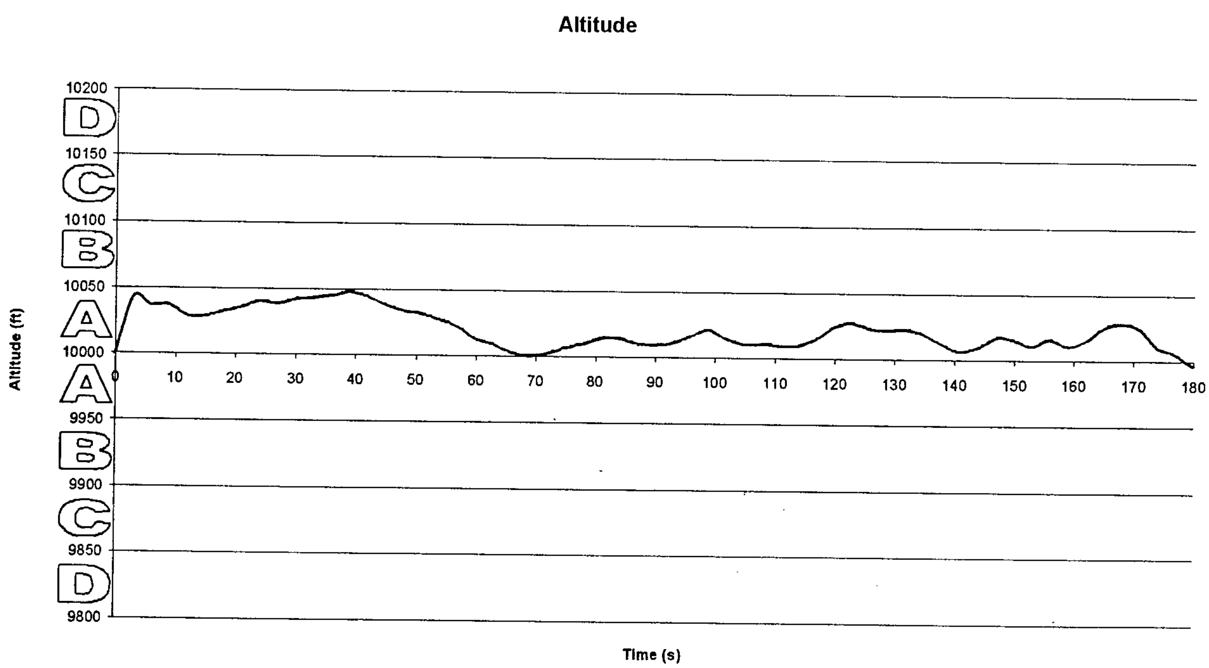


Figure 2.1 Altitude Versus Time, with Automated Grading of a Straight and Level Flight (Figures 2.1 to 2.4 represent the same flight.)

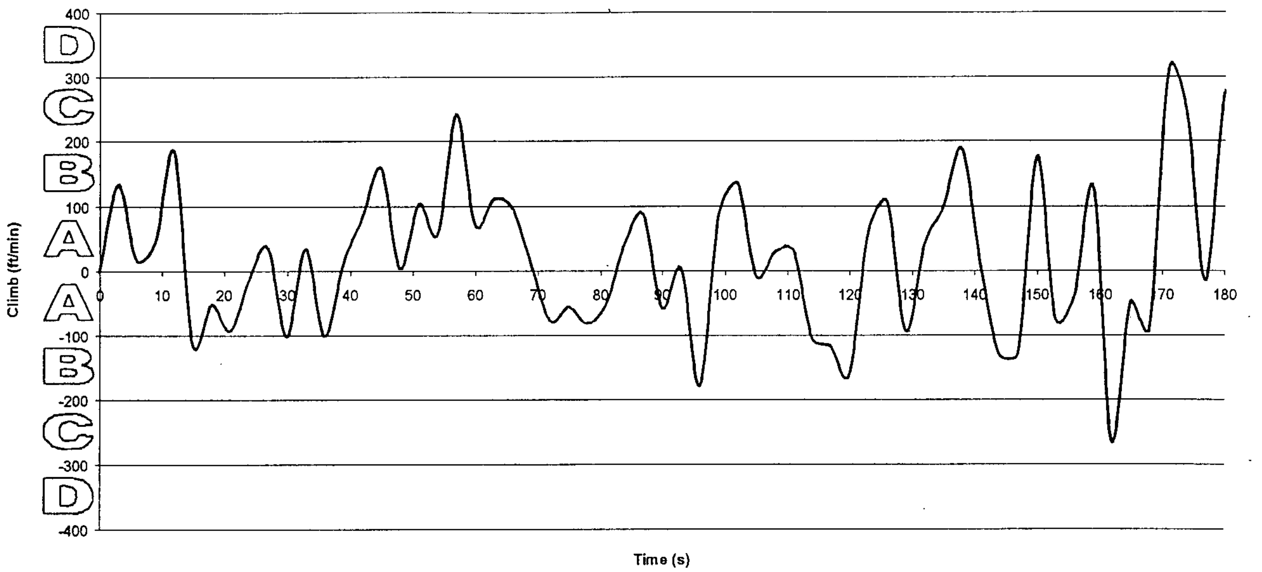


Figure 2.2 Rate of Climb Versus Time, with Automated Grading of a Straight and Level Flight

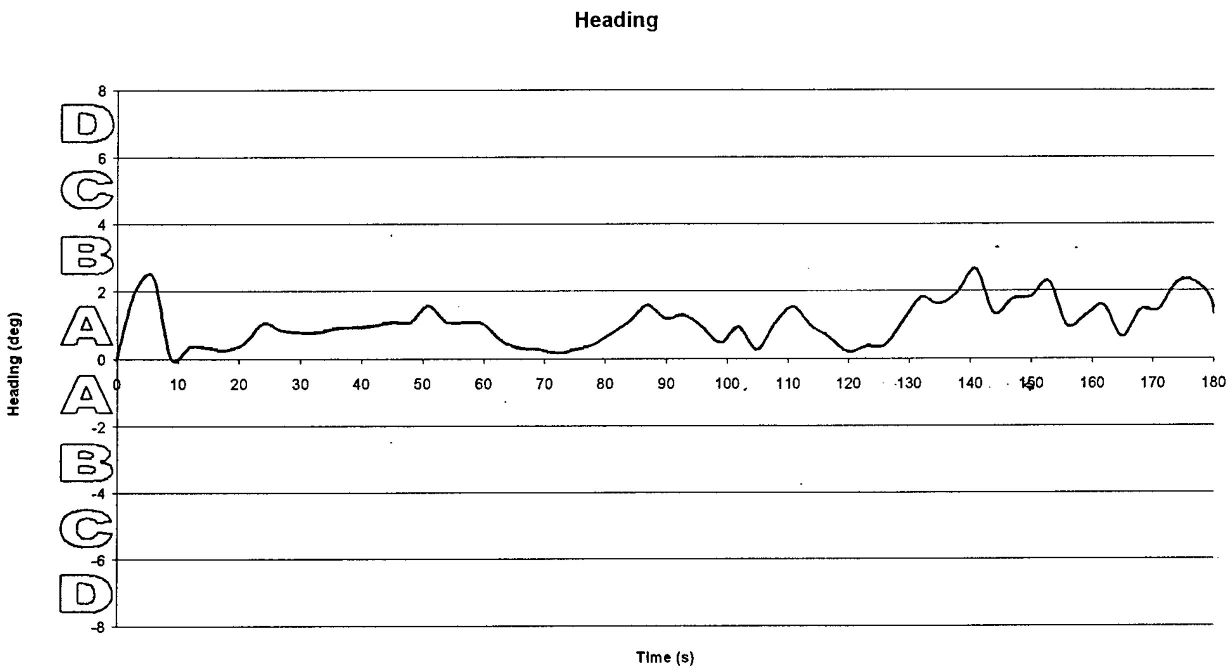


Figure 2.3: Heading Versus Time, with Automated Grading of a Straight and Level Flight

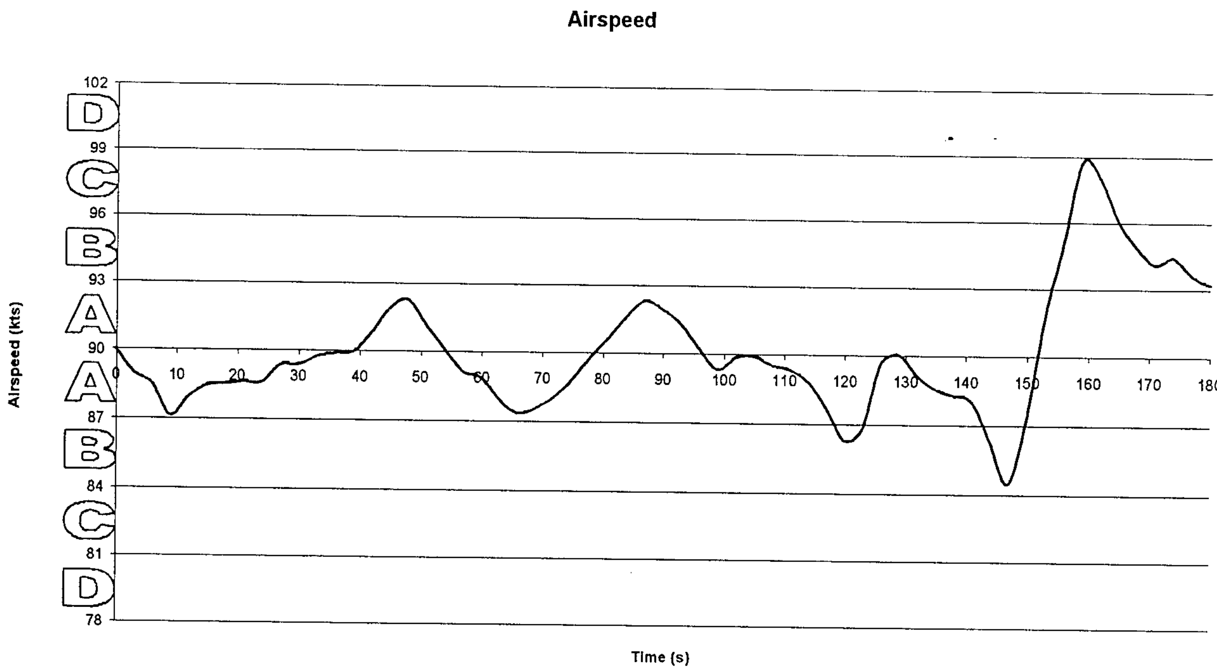


Figure 2.4 Airspeed Versus Time, with Automated Grading of a Straight and Level Flight

2.3 Procedure for Performance Measures Evaluation

Six students from Tuskegee University with a range of flight experience from medium flight knowledge to certified piloting participated as volunteer pilots on the simulator. Because of the nature of this experiment for performance measures, students with flight knowledge were desired in order to get adequate readings at different levels of performance. Each one of the six participants typically flew the following seven flights of three minutes duration:

Straight and Level flight with altitude graded
Straight and Level flight with heading graded
Straight and Level flight with airspeed graded
Straight and Level flight with altitude, rate of climb, heading and airspeed graded
Level Turn flight with heading and bank angle graded together
Level Turn flight with altitude graded
Climbing with altitude, rate of climb, and heading graded together

For every flight, a Microsoft Excel table of required parameter values and tolerance at three-second intervals was used as input file for grading of the flight. The input files and output for straight and level flight, level turn flight, climbing flight, and test may be seen in Appendix II. While a flight is operated, a visual basic code interacted with the input file and the simulator operating data files to monitor and score the flight parameters. The automated score files thus generated by the code contained the parameter values attained in the flight and the respective

grade points at the desired three-second intervals. A separate code used the automated score files as its input and generated the graphs of heading, altitude, rate of climb, and airspeed versus time labeled with 'A,' 'B,' 'C,' and 'D' grade regimes. A set of such graphs is provided in Figures 2.1 to 2.4.

The grade point averages for the desired set of parameters for every 30-second stamp up to 180 seconds were also calculated from the automated score files. Such grades are termed as the automated grades. A certified flight instructor independently observed the participants' flights and provided grades for every 30-second segment of the flights. Those grades are termed as the instructor's grades (refer to Appendix III).

2.4 Results from Performance Measures

Vreuls and Obermayer (1985) have recognized three common ways to validate the performance measures. In one of the three ways, the grades based on the proposed performance measures are compared with the judgments of performance provided by a sample of experts. For the present effort, the judgments were obtained from one qualified flight instructor instead of a sample of experts.

The automated grades based on performance measures versus instructor's grades are shown in Figures 2.5 to 2.8. In addition to the experimental points, the figures also have the best fitting lines based on linear regression for different sets of the experimental points. Figure 2.5 represents straight and level flights when heading and airspeed are graded together. Figure 2.6 also represents grading of straight and level flights, but three different sets of graphs represent separate monitoring of altitude, heading and airspeed. Figure 2.7 represents level turn flight with one set of points for grading of altitude and the other set of points for combined grading of heading and bank angle. Figure 2.8 represents climbing flight with grading of altitude, rate of climb, airspeed and heading. It is interesting to see the values of correlation coefficients obtained for the linear regression fitting. The correlation coefficients of 0.971 and 0.901 between automated grades and instructor's grades for all parameters of straight and level flight and for airspeed of straight and level flight suggest that their automated grades are acceptable. The correlation coefficients of 0.110 and 0.301 for heading and bank angle grading of level turn flights and for all parameters of climbing flights suggest that their automated grades are not acceptable and the corresponding performance measures must be revised.

Before the revision of performance measures for flight maneuvers other than straight and level flight, it would be worthwhile to explore two possible reasons of small correlation: 1) the software is not capturing and combining the parameters as specified, or 2) the instructor pilot was focusing on such aspects of the flight as smooth performance or integrated control inputs instead of placing emphasis on parameter tolerances.

Figure 2.5: Automated grade versus instructor's grade of the 30-second segments of straight and level flights.

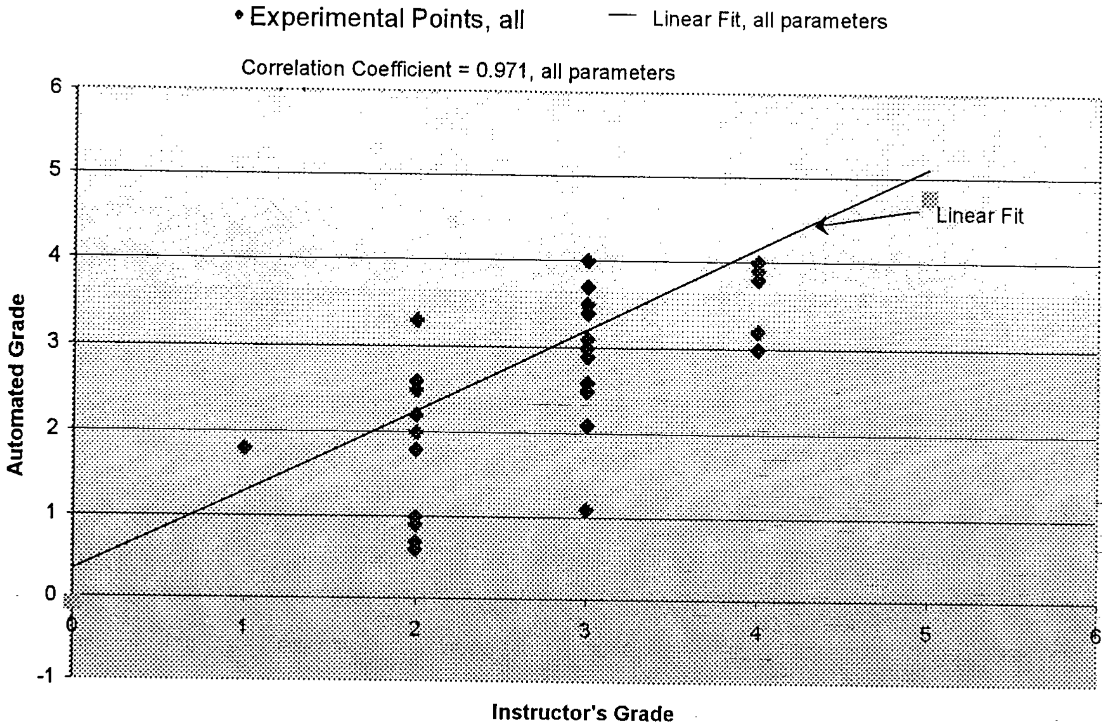


Figure 2.6: Automated grade versus instructor's grade of the 30-second segments of straight and level flights.

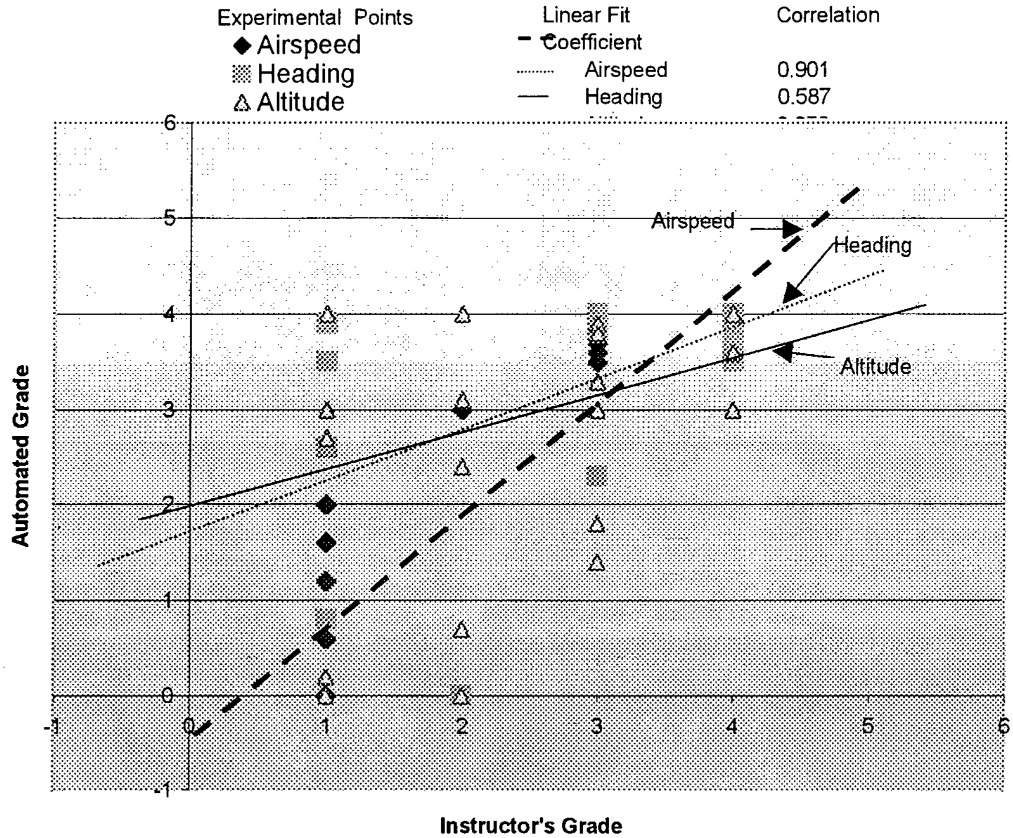


Figure 2.7: Automated grade versus instructor's grade of the 30-second segments of level turn flights.

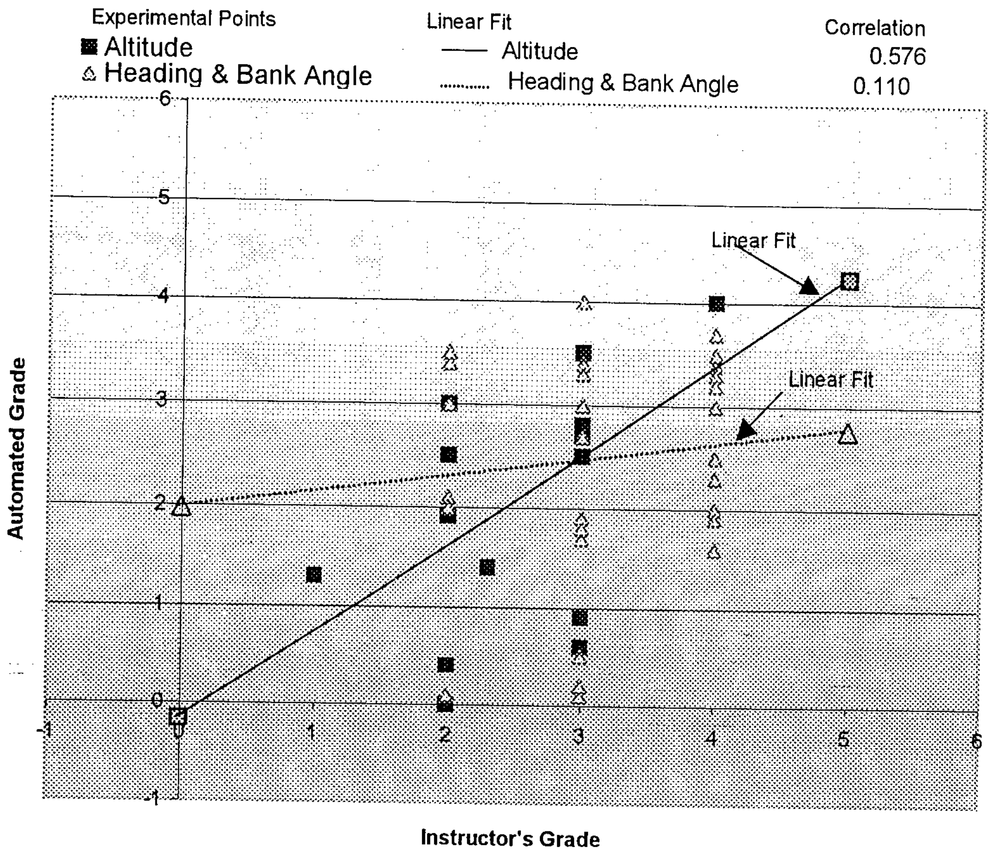
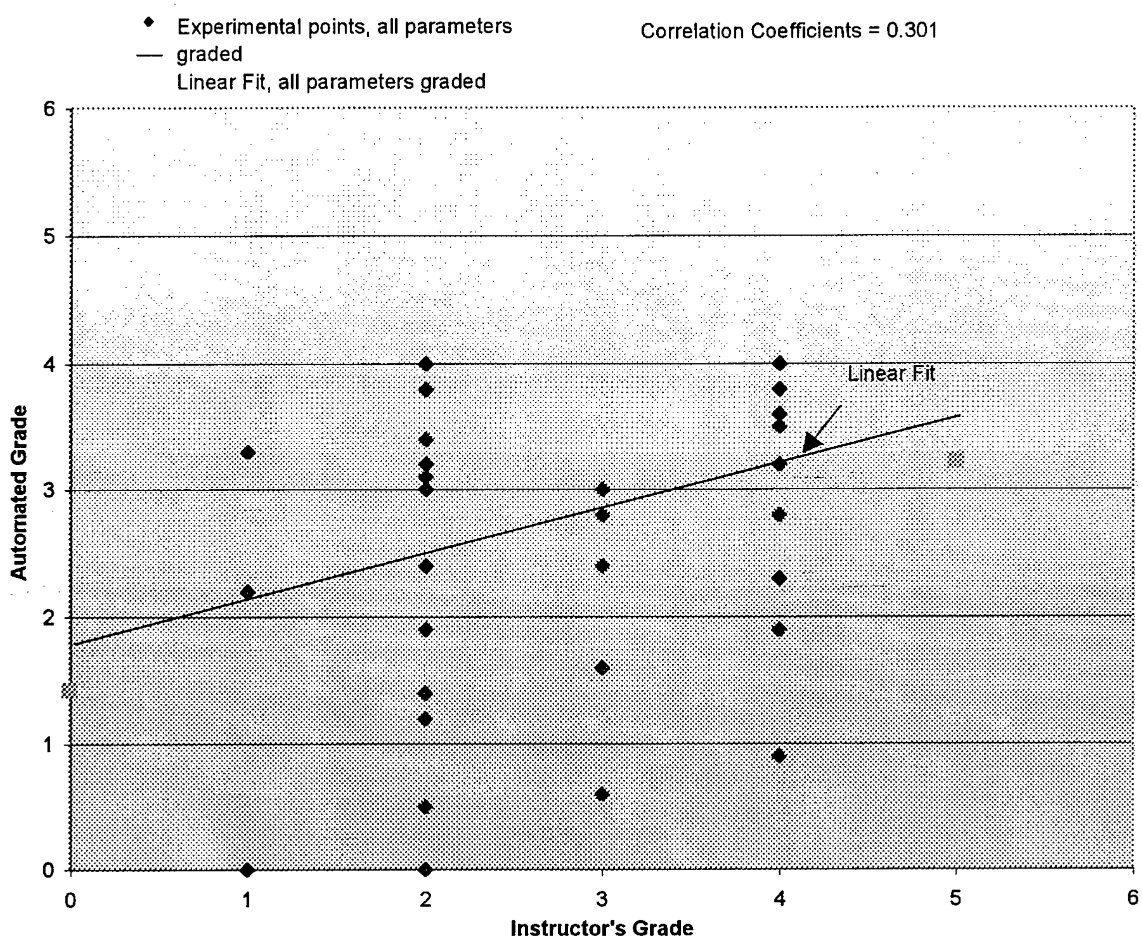


Figure 2.8: Automated grade versus instructor's grade of the 30-second segments of climbing flights.



2.5 Summary of Performance Measures

There are a number of possible ways to enhance the performance measures. Some form of video playback after the flight would be helpful, so that the instructor can possibly review the points given or have the flight examined by a second instructor. The tolerance levels can also increase for a more complicated maneuver without losing the integrity of the flight. The need to establishing a derivative check for the pilot returning to the desired parameter within a given time period can also be implemented. This procedure would utilize the time it would take once the pilot has deviated off course and how long it took the pilot to correct the off status. A correlation between the control inputs of the aircraft can be examined along with the movements of the rudder and aileron together within an integrated turn or other maneuvers. Utilizing more than one pilot to score the flight and then comparing all of the scores together, including the computer score, can determine a better correlation through the averages obtained.

It is necessary to understand that when the computer is scoring the flight, it does not get fatigued or miss any time stamps that are pre-programmed in the software. Although there was a strong correlation between the instructor grade and the computer grade during straight and level flight, the correlation between the two during the level turn and climb was off. One possible explanation is that the automated performance measures were acceptable, but the task of monitoring a number of parameters simultaneously was difficult for the instructor. The question is who do you trust, the instructor pilot or the computer. This question can be answered if the above changes or additions can be made, then a possible relation between both scoring systems can be evaluated.

CHAPTER 3: METHOD

3.1 Experimental Design

The independent variables studied in this experiment were the use of automated feedback versus no feedback, and real time training versus a combination of real time training and above real time training. Participants were randomly assigned to one of three experimental groups. The groups were real time training with feedback (RTWF), real time training without feedback (RTWOF), and real time/above real time training with feedback (RT/ARTWF). All groups received two sessions of training consisting of straight and level flight, climbs, and then turns. Participants in the RTWF and RTWOF groups first experienced four flights of straight and level, two climb flights, and two turn flights. This sequence was repeated on the second session. All training sessions for these two groups were conducted in real time. Participants in the RT/ARTWF group experienced their first session in real time, which was identical to the first session of the other two groups. However, on the second session, the training occurred in above real time, at 1.5 times real time. It consisted of six straight and level flights, three climb flights, and three turn flights. Participants in the latter group received the same amount of training minutes as participants in the first two groups, but more lessons. One should note that in RTT every flight was completed in three minutes, and in ARTT every flight was completed in two minutes.

Every participant experienced the following sequence of events:

Video familiarization
Training session 1
Training session 2
Testing

All participants received the same familiarization video before the training and the same tests in real time upon completion of training. Training sessions 1 and 2 keep the pilot from getting bored with the same tasks of level flight, climbing, and turning. The test consisted of two three-minute flights, which required flying straight and level, climbing and turning. Table 3.1 shows the timeline for the three groups according to the sequence of events and their appropriate time. Notice that each group completed the training in the same amount of time. For ARTT the group had more flights but completed them in the same time.

Table 3.1 Timeline of the Three Groups, with Number of Flights Performed in the Box

Groups 1 and 2

Video	Straight & Level				Video	Climb I		Turning I		Straight & Level				Climb II		Turning II		Test I & II	
	1	2	3	4		5	6	7	8	9	10	11	12	13	14	15	16	1	2

0 9 21 24 30 36 48 54 60 66

Group 3

Video	Straight & Level				Video	Climb I		Turning I		Straight & Level					
	1	2	3	4		5	6	7	8	9	10	11	12	13	14

0 9 21 24 30 36 48

Climb II		Turning II				Test I & II	
15	16	17	18	19	20	1	2

48 54 60 66

3.2 Participants

The participants in this experiment consisted of twenty-one undergraduate college students. These students volunteered their time without any incentives. In preliminary studies with flight simulator training, it was established that novice pilots rarely achieved satisfactory (C) level performance throughout a typical training session. Because of this, an effort was made to recruit participants who had either a few flying lessons or had some experience in a flight simulator or initial ground training. Actual pilots were not allowed to participate. Refer to Appendix III for pilots' level of expertise.

3.3 Apparatus

A mock setup of a partial cockpit was constructed and used as the pilot training station. Pilots were provided with a panoramic view using three monitors for the out-of-window display and a fourth monitor used for the instrumentation panel located below the out-of-window monitors. The Heads-Up-Display (HUD) was visible on the center monitor. A Heavy Metal Computer, a joystick and a keyboard governed the four monitors (see Picture 1 for the cockpit design used in this experiment).

The basic Heavy Metal Computer was available from Quantum 3D in Lake Forest, California. For the present research project, SDS International in Orlando, Florida, configured the computer. It has two Pentium II 400 MHz processors, 400 MB RAM, three extra display cards to drive the three monitors and a Sound Blaster audio card. A fifth monitor was used for the scoring and post-flight feedback system. The flight simulation software is LiteFlite version 3.3 available from SDS International, Inc. LiteFlite offers flight simulation of several aircraft including a Predator Unmanned Aerial Vehicle (UAV) system (refer to Appendix III). A single Predator airplane is relatively easy to control. To correspond with Predator data, the students on the simulator were required to fly at an airspeed of 90 kts at 10,000 ft altitude for most of the training flights.

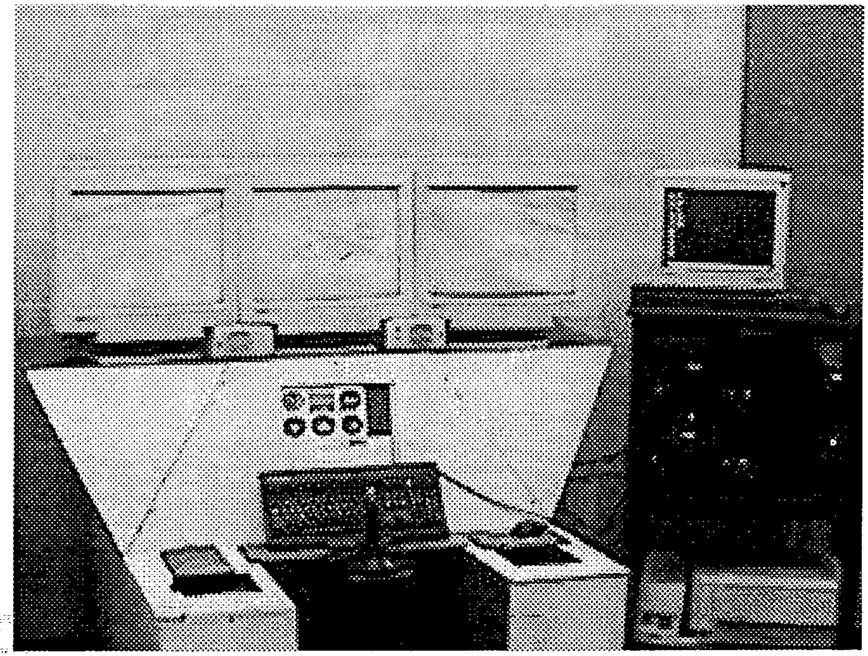
For the computer output version, Microsoft® Excel2000 Visual Basic® for Applications was used to generate the graphs and GPA of the pilots after the flights.

3.4 Flight Curriculum

The flight-training curriculum consisted of three types of flights:

Straight and Level
Climbing
Turning

For each lesson the flights were documented in a strip-chart format and script, and given to the student to review before and during the flight. For straight and level, the pilot was to take charge of the flight at 10,000 ft. altitude, heading N at 360° at 90 knots. This became the initial trim for all three levels of flight. Next, the pilot was instructed to maintain the same altitude, heading, and airspeed for the duration of 180 seconds.



Picture 1: Setup of Flight Simulator with Scoring Feedback Monitor to the Right

During climbs, the same initial trim was required. However, at specific times during the flight the pilot was to perform one climb at 500 ft/min, another climb of 1000 ft/min, and finish the flight with an altitude of 11,000 ft.

During turns the same initial trim was required, and in this lesson the pilot was required to make two level turns. The first turn was a heading change from North to South at a bank angle of 30°. The second turn involved changing the heading from South to North with a bank angle of 45°. Both maneuvers were to be performed at the appropriate times according to the flight script. The level of difficulty as assigned by a consulting flight instructor can be observed in Table 3.2 for each of the flight lessons. Table 3.3 shows the level of difficulty for the two tests required at the end of training.

3.5 Procedure for Participants

Participants were asked to volunteer approximately two hours of their time to participate. Upon arrival, the participants were asked to fill out a consent form and a background survey form that consisted of questions about their level of flight training experience. They were then assigned a student code to protect their confidentiality. After the forms and survey were signed, the student was ready to begin the first stages of training. Students were provided ample opportunity for breaks and refreshments if needed.

Table 3.2 Flight Lessons with Level of Difficulty and Time Required

Flight Lesson	Degree of Difficulty			Key Instruments Necessary for Maneuvering							Time in maneuver (seconds)
	Easy	Medium	Hard	VSI	TC	HI	BAI	ASI	ALI	AI	
Level	X					X		X	X		180
Climbs 500 ft/min		X		X		X		X	X	X	60
1000 ft/min			X	X		X		X	X	X	30
Turns 30° bank			X		X	X	X	X	X		54
45° bank			X		X	X	X	X	X	X	48

Table 3.3 Level of Difficulty for the Two Tests

Flight Lesson	Degree of			Key Instruments Necessary for							Time reqd. in maneuver
	Eas	Mediu	Har	VSI	TC	HI	BAI	ASI	ALI	AI	
Test 1 Climb		X		X		X		X	X	X	30
500 ft/min			X	X		X		X	X	X	60
Descend 500 ft/min			X		X	X	X	X	X		27
Test 2 Climb		X		X		X		X	X	X	60
500 ft/min			X	X		X		X	X	X	30
Descend 1000			X		X	X	X	X	X	X	27

Note: In ARTT the level of difficulty will increase significantly for climbs and turns.

For every flight the total flight time is 180 seconds.

Terms for Tables 3.2 & 3.3

VSI- Vertical Speed Indicator
TC – Turn Coordinator
HI – Heading Indicator
BAI – Bank Angle Indicator
ASI – Airspeed Indicator
ALI – Altitude Indicator
AI – Attitude Indicator

3.6 Familiarization

In the familiarization portion of the program students were required to watch a fifteen-minute video that addressed the entire flight program (refer to Appendix I). Due to the complex nature of the task and the fact that these participants were relatively naïve about the task, participants were given a list of terms and definitions that were used in the video. The first portion of the video provided an overview of the control stick and throttle operations, and then demonstrated their use in performing coordinated control inputs to execute the flight maneuvers such as climbing and turning. The next part of the video identified the most important Heads Up Display (HUD) information that corresponded to the flight lessons such as altitude, airspeed, and heading. It also addressed the instrument panel indicators such as artificial horizon, vertical speed indicator, and bank angle indicator that must be monitored and managed in order to properly perform the given task. The knowledge obtained would provide a better understanding of the simulator and how to effectively perform a visual scan of both the HUD and instrument panel while using the control stick for inputs and maintaining the correct flight parameters. The video also instructed the pilot on how to perform climbs and turns during flight. Segments of the video corresponding to the task about to be performed were presented just prior to training on that task. After the video presentation the participants were seated in front of the simulator and allowed to ask any questions relevant to the flying tasks at hand.

Participants were also informed of the different types of feedback they would receive according to the group in which they were placed. In the 1st and 2nd groups audio cues were present and the post flight strip chart option was available. The audio cues were activated when the pilot went out of bounds for altitude or heading. If the pilot climbed to 10,200 ft or descended to 9,800 ft the audio cues would be triggered until the pilot corrected his or her position. The audio cues would also be emitted when the pilot exceeded the out of bound limit of $\pm 8^{\circ}$ for heading; at this time the pilot would have to correct the heading in order to turn off the audio cues. It should be noted that when the audio cues are on, the pilot receives a zero score for the appropriate parameter.

The other form of feedback the pilot received was the post flight strip chart. This chart was available to the student after the flight. It showed the altitude, heading, rate of climb, and airspeed of the flight being scored. The strip chart showed each of the parameters versus time in seconds.

After orientation with the audio cues and strip charts, participants were informed of the first flight they would have to perform. They were also given the flipchart they would use to coordinate that flight. The flipchart was provided to assist the student in managing his or her flights and maneuvers at the appropriate time intervals. Each of the lessons and both tests were provided in the flipchart for the pilot to review and observe during the flights. Pilots were instructed to try to maintain the flipchart's flight plan in order to achieve maximum scoring.

3.7 Scoring

Participants were instructed on the scoring procedure and how to obtain the highest possible score without going out of bounds. For grading or scoring of a flight, sampling is done as a single "snapshot" of each monitored parameter at the instant in time governed by a pre-specified time interval. This can be referred to as "time slice" sampling. For basic task flights, grading is done at every sixth-second interval for straight and level segments and at every three-second interval for a maneuvering segment such as climbing and turning. The few seconds occurring while entering and leaving a maneuver were not graded.

Maneuvers were scored based on four points for an 'A' score, three points for a 'B' score, two points for a 'C' score and one point for a 'D' score. Beyond 'D' no points are given in the score. The tolerance allowed varied from flight to flight. For instance, in straight and level flight where all four parameters are being graded, there is a tolerance of ± 50 feet for altitude, ± 100 feet/min for rate of climb, ± 3 degrees for airspeed, and ± 2 degrees for heading. For climbs and turns not all parameters were graded, but the points were calculated in the same manner (refer to Appendix II for scoring example).

3.8 Training

Training took place immediately after all questions and concerns were addressed from the participant. Training lessons were separated into two sessions to keep the pilot from getting over-tasked with the same lesson repeatedly (refer to Table 3.1). The experimenter, who was familiar with the flight guideline, guided the pilot through the first flight of each lesson. This assisted in instructing the pilot on how to maintain the proper parameters. After the first flight, pilots completed the remainder of flights on their own. After each flight, the experimenter reviewed the pilot's score and strip chart if they fell into the group that was designated for feedback with strip charts. This would be the only interaction between pilot and experimenter. Training continued until both sessions were completed and scores assessed for the pilot.

3.9 Testing

After the training lessons participants were given two tests in real time without feedback. Both tests given to the pilots involved all three parameters of training in the training sessions. Pilots were provided the flipchart and enough time was given for them to read and understand what was expected of them in the test flights. After the completion of both tests, they were briefed on their scores and their overall performance during the entire program.

3.10 Simulator Fidelity

For the simulator of Predator Airplane used in the present study, certain checks on validating its fidelity were performed in a separate study reported by Williams, 2000[1]. Checks included time to turn in a level flight, static longitudinal stability, maximum lift to drag ratio, and maximum rate of climb at various speeds and altitudes. Simulator fidelity was found acceptable for the present work.

3.11 Results and Discussion

Figure 3.1 presents the grade point average (GPA) of every flight in the training and testing sequence averaged over the seven students per group. As an example, the GPA in the first straight and level flight averaged over the seven students of Group One equals 2.007 (Appendix III, Table 10). It is shown by a triangle at three minutes time, because completion of the first straight and level flight corresponds with three minutes of training time. As another example, the GPA in the second climb flight averaged over the seven students of program three equals 1.175 (Appendix III, Table 12). A diamond represents data from this group at 18 minutes because completion of the second climb corresponds with 18 minutes of training time. To consider the three training groups, use Figure 3.1 as a reference.

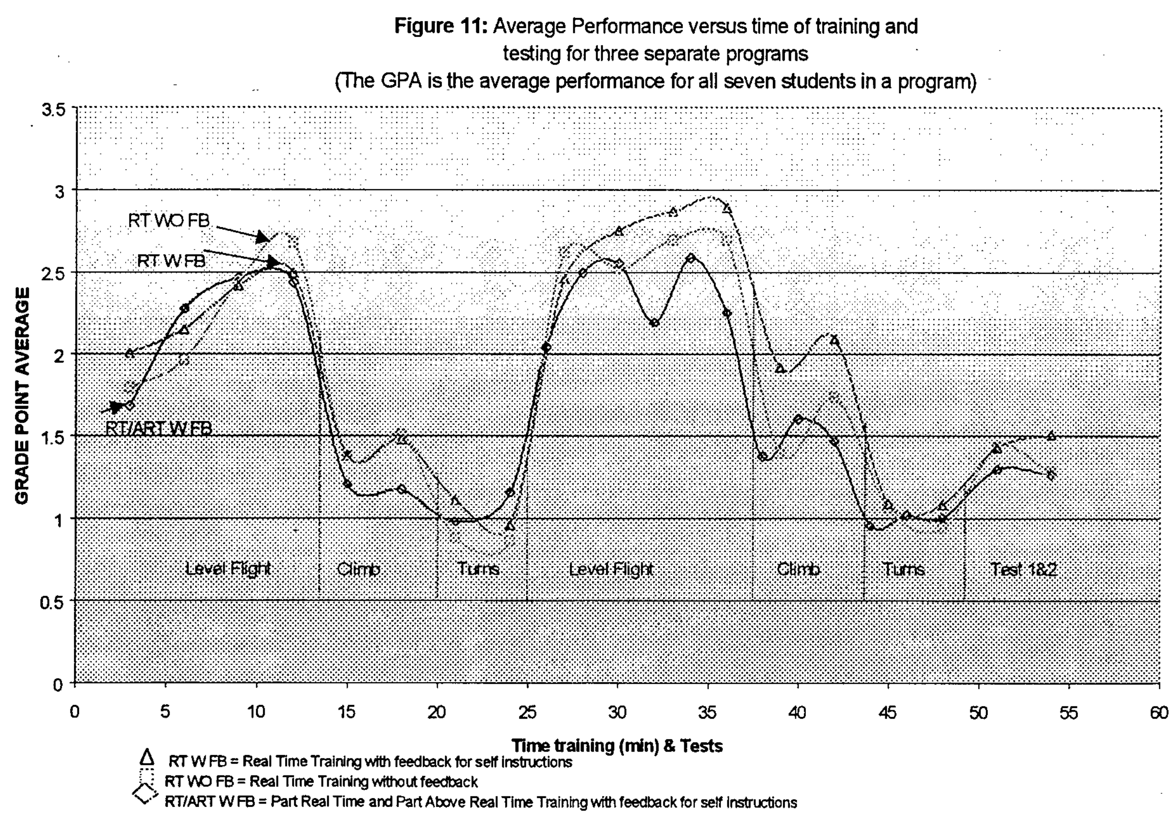


Figure 3.1 Average Performance Versus Time of Training and Testing for Three Separate Programs

In Group One (RTWF), students were trained in RT with feedback as a form of self-instruction. In the training intervals from 0 to 12 minutes and from 24 to 36 minutes of level flights, a steady increase of 0.05 points per minute in the GPA was visible. The average climb performance also showed a steady increase in GPA at a rate that is about half of that in the level flight performance. In the first set of turning flights between 18 to 24 minutes, a drop in average performance was also noticeable. In the second set of turning flights between 42 to 48 minutes, there is no visible increase in performance. Moreover, the performance in the second set of turning flights did not show anything beneficial when comparing the 24 to 42 minutes of training in level flights and climb flights. Finally, in this Group the GPAs in turning flights are the lowest when compared with GPA values of level flights and climb flights.

In Group Two (RTWOF), students were trained in RT without any feedback. In the training interval from 0 to 12 minutes of level flights an increase in performance was visible, but from 24 to 36 minutes the rate of increase appears to become flattened or asymptotic. The nature of changes in performance for climb and turns are not different from those in the RTWF Group.

For Group Three (RT/ARTWF), students are trained with feedback as a self-instructional tool; they received RTT from 0 to 24 minutes and ARTT from 24 to 48 minutes. It was noticeable that from 0 to 24 minutes the performance trends are about the same as those in Group One, except for the turning flight where the performance did not decrease with the training time. For Group Three, the performance from 24 to 48 minutes is very significant. In this training interval ARTT was used at 1.5 times RT. Accordingly, the number of flights in this interval is 6 level, 3 climbs and 3 turns as opposed to 4 level, 2 climbs, and 2 turns in Group One. Although ART should make flying more challenging, a visible decrease in performance was not found from 24 to 48 minutes when compared with the performance from 0 to 24 minutes. A possible reason may be that without any distractions like gunnery tasks or emergency measures, the level, climb or turning tasks performed one at a time are not highly complex; thus, they do not become excessively challenging in ART when compared with RT.

While observing the training program, it was noticed that for the straight and level flight the degree of challenge is about the same in both RT and ART, but for climbing and turning flights ART operation makes the tasks more challenging when compared with RT operation. In agreement with this observation, it appears that the climb and turn performance in ART from 36 to 48 minutes is not degraded compared with RT because of the benefit of training from 0 to 36 minutes. A certified private pilot independently supervised three students trained in three different modes: RTT alone, ARTT alone, and ARTT as top-off training. This pilot recorded in his observation that when an above-real-time trained student flew in real time, flying seemed much slower, and the student could pay more attention to the flight objective.

It is understood that climbs and turns in simulator training offer a greater challenge than straight and level flight, as noted from the performance measures. This can be referred to Fitts and Posner's (1967) three stages of skill acquisition: cognitive, associative and autonomous. As noted in the introduction, one might infer that for a more complex task, ARTT would be more effective at the autonomous stage, and for a less complex task, ARTT can be adopted at the cognitive stage. It is therefore proposed that ARTT alone for training on straight and level flight

would be effective, and the improved time efficiency would be beneficial. On the other hand, ARTT as top-off training would be effective for the climbing and turning flights.

For RTT with feedback, an increase in performance on level flights with the amount of training was visible until the advanced stages of training. An increase in performance with the amount of training was limited to the initial stages of training when feedback was absent in RTT. Therefore, the students who had not received feedback were at a disadvantage. A consistent increase in performance with the amount of training was not apparent in the RTT and ARTT portion of the program, although the students received feedback. Perhaps the difference in training modes from RT to ART at the 24th minute was masking a possible increase in performance.

The test scores of the subjects in three different modes of training were not significantly different. Moreover, these test scores are too low to warrant a definitive comparison of the different training modes. The analysis of variance calculated according to D.B. Wright (1997) was applied to the test scores of all the participants in three different groups representing the three modes of training respectively. The F ratio $F(2,18)$ equaled 3.747 where for $\alpha = .05$ the critical F is 3.55, and for $\alpha = .01$ the critical F is 6.01. The low scores overall for all three groups indicate that the task may be too complex to master in the training period allowed.

Figure 3.2 shows the individual straight and level flights with just the straight and level portions extracted from the two tests. Groups 1 and 2 from the figure offer no significant differences for the straight and level portions of the tests. Group 3 however, shows a

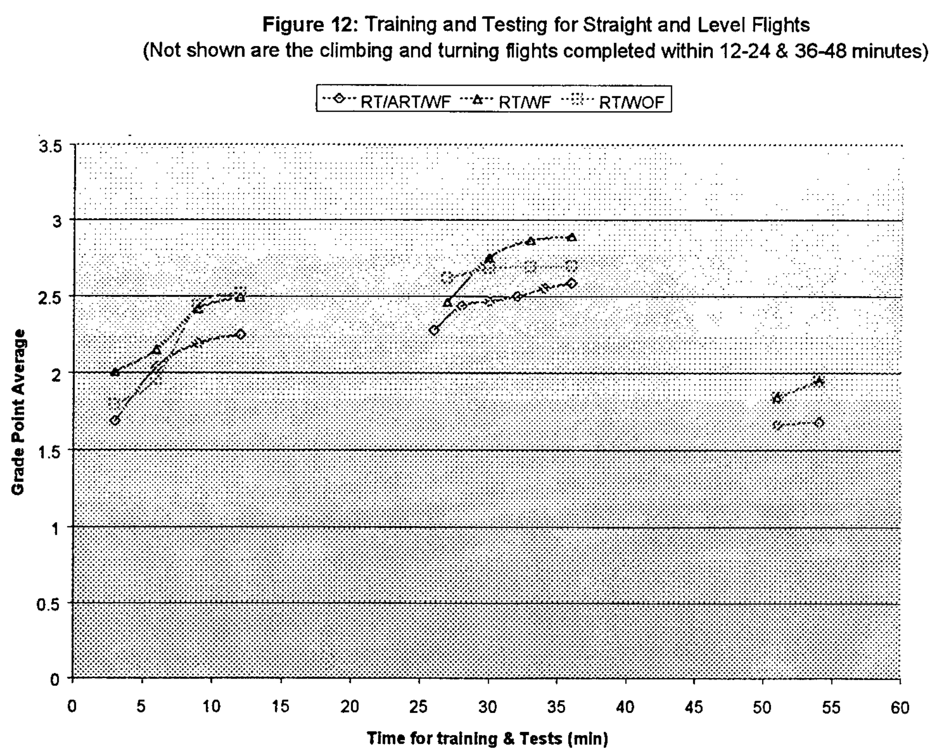


Figure 3.2 Training and Testing for Straight and Level Flights

significantly lower test average then the other two groups. The F ratio for the average performance in the first and second tests equaled 0.18 for students trained under three different training programs. Therefore, the test scores are not significantly different. The experimenter noted that as the trainees would start off the tests with the initial straight and level portions, the pilots were able to maintain the flight within the required tolerances. But as the tests required more complicated maneuvers within the specified time frame, it was harder for the pilot to keep up and therefore ended up in a position of lagging behind in accordance with the flight plan. Therefore, the tests average represents the performance of the pilot at all the straight and level portions of the test, whether they were in the flight plan's time frame or not.

3.12 Recommendations

Based on the present work, an additional set of experiments is suggested as further work on self-instructional strategies and above-real-time training. Before conducting the experiment, the performance measures will be reviewed and revalidated. Allen et al (1986) noted that individuals with different abilities and aptitudes might require different modes of instruction during training. This could lead to programs designed for different individuals with different levels and interests. The training and testing of a participant will consist of familiarization, preliminary level flight training, and pertinent flight maneuver training and testing. A brief description of every item is as follows:

<u>Familiarization:</u>

Instructor interacts with student to ascertain student's familiarity with flight and airplane terms, which are projected in the instructional video.

Student will watch instructional video on straight and level flight.

<u>Level Flight Training:</u>

Student will operate the three-minute straight and level flight performed in two minutes at 1.5 times real time until the student scores 'B' or better grade in two consecutive flights without requiring emergency measures. The student will operate more straight and level flights at 1.5 times real time with the requirement of emergency measures until a 'B' or better grade in two consecutive flights is achieved. Let us note that in straight and level flights in the present study, the 21 volunteers on average reached a high 'C' grade (see Figure 3.1) and 9 of them reached a high 'B' grade (see Appendix III, Tables 9, 10 & 11). It is estimated that depending upon students' background and aptitude, the numbers of required flights to reach 'B' performance will vary between 4 and 20. At this point, the student is ready for participation as a subject in an exploratory experiment composed of flight maneuvers in training and testing. Every flight in maneuvering training should include a number of emergency procedures. The in-flight and post-flight feedback for self instruction will consist of trending out-of-bound audio cues, out-of-bound audio cues during a flight, and strip charts showing the monitored parameters versus time after a flight is completed. For training in-flight maneuvers, every participant will be shown a video on flight maneuvering. Participants will then be divided in three different groups:

(i) RTT with no feedback
(ii) RTT with feedback: trending out, out-of-bound audio cues, and strip charts
(iii) RTT for the first 18 minutes of training and ARTT for the next 18 minutes

A module of training will consist of one straight and level flight with acceleration and deceleration, one climb and descent flight, and one right and left level turn flight. Four training modules will be completed in RTT, and five modules (two in RTT and three in ARTT) will be completed in the RTT/ARTT mode. Upon completion of training, the test flights will be given in RT, and every test flight will require acceleration, deceleration, climb, descent, right and left level turns, and emergency measures. No feedback will be provided in the test flights except at the end of the test. The participant will be briefed on his or her grade and will be required to complete a form pertaining to evaluation of training.

CHAPTER 4: CONCLUSION

The study of flight training on simulators was conducted in two components: development of performance measures for a trainee's flight and comparison of different training strategies, and performance measures and automated scoring of simulator based flights used for comparing students' performances in training and testing. Performance measures derived from prescribed tolerances in different parameters of straight and level flights gave rise to acceptable automated scoring when compared with the respective scoring of the same flights provided by a qualified flight instructor. For scoring of level turn and climbing flights, the simple criteria of tolerances in different parameters did not work. It is proposed that two or more qualified flight instructors must evaluate video playback of several simulator flights. Then the automated scores of the same flights based on different exploratory measures of performance can be compared with instructors' scores.

To find the effects of self-instructional methods and Above Real Time Training (ARTT) for basic flying tasks on a simulator, twenty-one university students were trained and tested on a flight simulator. Each student was trained in one of the three alternate programs and then tested in Real Time. The training program included straight and level flight, climb and level turns. To draw conclusions for the climb and level turns, further work is required to improve the performance measures. The following conclusions are limited to the training of straight and level flight.

In the first program, the students were trained in Real Time with in-flight and post-flight feedback for self instruction; with increasing amount of training, an increase in their performance was visible until the end of the advanced stage of training. In the second program, the students were trained in Real Time without any feedback for self instructions; with increasing amount of training, the increase in their performance was limited to the initial stage of training and in Above Real Time for the advanced stage of training; with increasing amount of training, a consistent increase was not apparent in their performance although they received in-flight and post-flight feedback for self instructions at both stages of training. From the initial to advanced stages of training, a switchover from Real Time Flights to more challenging Above Real Time Flights might have masked the students' possible increase in performance. All students were

tested in the Real Time Mode. The average test scores for students trained in each of the three different programs were not significantly different. A consideration of the individual performances, however, suggests the need of tailoring of training program for individuals.

Within the respective chapters, there are discussions and suggestions for possible future work in the areas relevant to training on flight simulators.

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APPENDIX I

FLIGHT LESSON
VIDEO SCRIPT

INTRODUCTION

The purpose of this document is to provide a guideline for the development of an instruction video based on three (#'s1, 2 & 3) of the five lesson plans included in the USAF / TU flight simulation research study (see section below). This document is outlined in such a way as to serve as both a visual reference and a narrated script for each of the three aforementioned lessons.

Lesson Plans

1. *Orientation:* provides the subject with a sufficient overview of the physical flight controls as well as an orientation of the simulated instrument panel setup & HUD symbology in order for the subject to competently conduct all of the flight tests.
2. *Level Flight:* a straightforward task requiring the pilot to maintain a consistent heading, altitude, and airspeed.
3. *Climb / Descend:* a more demanding task requiring the pilot to perform a series of climbing and descending flight maneuvers at a specified rate in order to achieve a specified altitude in a fixed time duration.
4. *Turns:* the pilot is required to perform a series of horizontal turns at specified intervals in order to reach a specified heading.
5. *Tests I & II:* requires the pilot to perform each of the previous flight tests (2 to 4) consecutively.

GLOSSARY

ASI ≡ Airspeed Indicator	c-w, c-c-w ≡ clock-wise, counter-clock-wise	RTT ≡ Real-Time Training
AI ≡ Attitude Indicator	HI ≡ Heading Indicator	TC ≡ Turn Coordinator
ALI ≡ Altitude Indicator	HUD ≡ Heads Up Display	TU ≡ Tuskegee University
AOA ≡ Angle of Attack	PD ≡ Psychology Department	USAF ≡ United States Air Force
ARTT ≡ Above Real-Time Training	RCN ≡ Research Conductor Narrative	V ≡ Visual
ASED ≡ Aerospace Science Engineering Department	RoC ≡ Rate of Climb	VSI ≡ Vertical Speed Indicator

Pause | Stop | Q&A

VISUALS

V-1A: Title Screen
Title
TU & USAF
ASED & PD

V-1B: Close-up of the sim box.

V-2A: Close-up of the center monitor showing the *Startup menu.*

V-2B: Close-up of the center monitor showing the *Desktop screen* and *LiteFlite Startup Screen menu.*

V-1A (Intro): Full frame of the simulator.

NARRATIVE INSTRUCTIONS

Lesson #0: Orientation

Time = 10:00 min.

1. *RCN:* Initial setup of the simulator by the research conductor consists of the following actions:
   a. Toggle the *power switch* for the simulator computer to the *ON* position (allowing a few moments for the system to boot-up),
   b. Activate the *start-up menu* by pressing the *CTRL+ALT+DEL* keys, and enter the *password* at the *logon menu,*
   c. Single-click on the *START menu,* scroll up to the *Programs folder icon,* scroll to the *LiteFlite folder icon,* and finally, select the *LiteFlite™ Multichannel item icon* in order to start the simulation software.
2. *RCN:* Press the *enter* key at the *LiteFlite™ Session menu* (the default selection is already set) and the *LiteFlite™ Startup Screen menu* will appear. The research conductor will now be able to set-up the aircraft type, flight plan, instrument panel, and input scoring sheet by doing the following:
   a. Select ***Predator*** from the *Aircraft Type option* for the aircraft type,
   b. Browse for the ***scoring.afp*** (for RTT active scoring mode) or ***xscoring.afp*** (for ARTT active scoring mode) from the *Flight Plan option* for the flight plan,
   c. Browse for the ***tuskegee.idf*** from the *Instruments option,* and
   d. Press the *OK* button to start the simulation software,
   e. The *VBScript Select Scoring Criteria menu* then appears prompting you to enter the name of the scoring sheet to be used, ex. Level1, climb, etc…

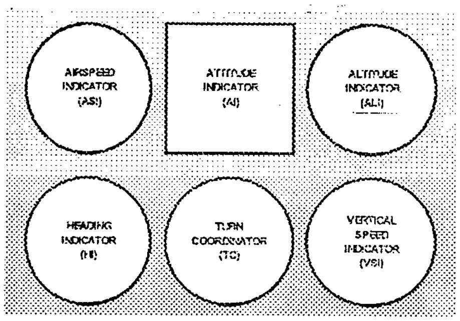
1. *RCN:* This is an instructional video for the evaluation of ARTT and self-instructional strategies for airmanship tasks on a flight simulator. The video is intended to assist the RC during the pre-flight briefing & post-flight de-briefing as well as during the interim flight evaluations and Q&A sessions:
   a. Briefings: the pilot will watch the video paying special attention to the hints and general notes, especially those for control inputs and HUD / instrument panel descriptions.
   b. Evaluations and Q&A: the RC will view the data generated during the most recent test flight with the pilot in order to evaluate the pilots' flight performance and make corrective observations. The RC will then answer any questions that the pilot may have or quiz the pilot as an informational review.

VISUALS

V-3A: Continue full frame of the simulator.

V-4A: Close-up of the control stick & throttle.

V-5A: Close-up of the instrument panel monitor.



NARRATIVE INSTRUCTIONS

2. *RCN:* The first flight lesson to be conducted is the Orientation flight. It's objective is twofold:
   a. First, the lesson will provide an overview of the control stick & throttle functions (with respect to the aircraft control surfaces), and then demonstrate their use in performing coordinated control inputs in order to "cleanly" execute the basic flight maneuvers, ex. climbing and turning.
   b. Second, the lesson will identify the most relevant HUD discretes (such as airspeed, heading, and altitude) as well as instrument panel indicators (such as the artificial horizon, vertical airspeed, turn coordinator, and heading) that must be monitored, assessed, and managed in order to efficiently evaluate the most pertinent flight information.

   The combined knowledge thus gained will illustrate how to effectively perform a visual scanning pattern of the HUD & instrument panel while simultaneously using controlled inputs to make corrective adjustments in order to accomplish the desired flight maneuver.
3. *RCN:* We will first begin with a familiarization of the a) control stick and throttle functions and then review the b) instrument panel and HUD layouts.
   a. The control stick provides the pilot with the most direct means of maneuverability & controllability of the aircraft's three axes of rotation during flight, i.e. the longitudinal, lateral, and vertical axes. The common reference point for the three axes is the airplane's CG, which is the theoretical point where the entire weight of the airplane is considered to be concentrated. The ailerons, elevator, and rudder create aerodynamic forces, which cause the airplane to rotate about the three axes. Control stick inputs will cause the airplane to pitch, roll or yaw about each of these axes, respectively:
      - Pitch attitude, which is the up and down movement of the airplane's nose, controls the rate of climb or descent; pulling back on the control stick causes the aircraft's elevators to deflect downward, thereby imposing a positive moment about the CG of the airplane, resulting in an upward pitching motion for climbing. The reverse is also true by pushing forward on the control stick for descent.
      - Left or right movements of the control stick direct the airplane's roll rate, by creating an immediate rolling motion. Since the airplane's aileron's always deflect in opposite directions, the aerodynamic shape of each wing and the associated production of lift is affected differentially; moving the stick to the left causes the right aileron to deflect downward, thereby increasing the AOA on the right wing while simultaneously deflecting the left aileron upward and decreasing the AOA on the left wing. The result is that the airplane will roll to the left because the right wing is producing more lift than the left.
        Note: As long as the stick is deflected, the airplane will continue to roll in that direction at that rate; only by returning the stick to neutral will the airplane stop.
      - Rotating the control stick with c-w or c-c-w twisting motions of the wrist allows the pilot to deflect the airplane's rudder to the right or left, thereby causing the airplane to yaw, which is the side-to-side movement of the airplane's nose.
   b. Located on the left-hand-side of the control stick is the throttle, which plays a unique role in indirectly influencing the aircraft's pitch attitude and, therefore its' ability to maintain a stable flight path; excess thrust will result in a positive deviation in attitude or AOA, whereas reduced thrust will have the opposite effect.
4. *RCN:* Just above the control stick setup is the instrument panel monitor, which displays various gauges & dials. Starting from the top-left corner of the panel in a c-w direction:
   - **Airspeed Indicator** (ASI): This dial displays the true airspeed of the aircraft in units of knots and is read in a c-w direction. Each large division represents 10 knots and each small division represents 5 knots.
   - **Artificial Horizon** (AI): Perhaps the most important display since it presents more information in one place than any other "head-down" instrument. It shows a view of the airplane, as it would appear from behind. The angle of bank is shown by the relationship of the miniature aircraft to the deflected horizon bar and by the alignment of the pointer with the bank scale at the top of the instrument. Pitch is indicated by the position of the center of the miniature airplane with respect to the horizon bar. The bank angle is marked in divisions of 10°. The attitude indicator also senses roll as well as pitch. The attitude indicator uses an artificial horizon (with the sky above and earth below) and miniature airplane to depict the position of your airplane in relation to the true horizon. As the airplane banks, the relationship between the miniature airplane and the horizon bar depicts the direction of turn.
   - **Altitude Indicator** (ALI): This dial shows the aircraft's true height above the SLS of the earth in units of ft.

VISUALS

V-5B: Continue close-up of the instrument panel monitor.

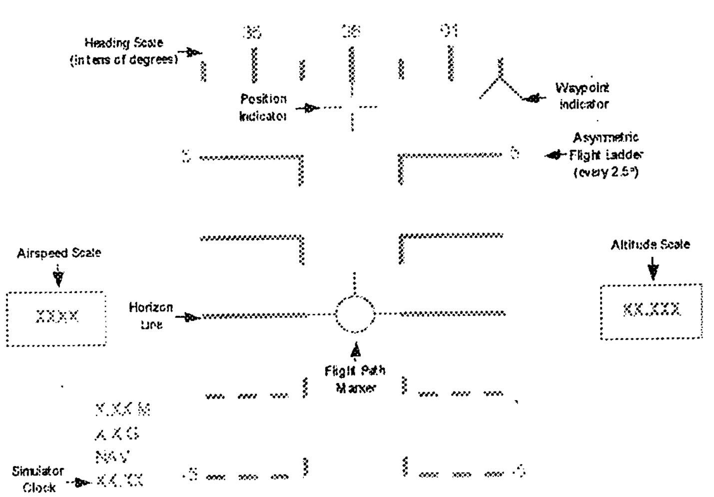
V6-A: Close-up of the HUD monitor.

NARRATIVE INSTRUCTIONS

- **Vertical Speed Indicator** (VSI): Shows the rate of climb or descent. Each large division represents 1000 ft/min and each small division represents 200 ft/min.
- **Turn Coordinator** (TC): When you are rolling into or out of a turn, the miniature airplane banks in the direction the airplane is rolled. A rapid roll rate causes the miniature airplane to bank more steeply than a slow roll rate. You can use the turn coordinator to establish and maintain a standard-rate turn by aligning the wing of the miniature airplane with the turn index. The inclinometer is used to depict airplane yaw. It consists of a liquid-filled, curved tube with a ball inside. During coordinated, straight-and-level flight, the force of gravity causes the ball to rest in the lowest portion of the tube, centered between the reference lines. You maintain coordinated flight by keeping the ball centered. If the ball is not centered, you can center it using the rudder. To do this, you apply pressure on the side where the ball is deflected. The simple rule, "Step on the ball," may help to remember which rudder pedal to depress. Centering the ball will result in a coordinated turn.
- **Heading Indicator** (HI): Senses the airplane movement and displays heading based on a 360° azimuth, with the final zero omitted. In other words, 6 indicates 60°, 21 indicates 210°, and so on.

5. Located above the instrument panel monitor is the HUD, which will provide much of the visual flight information for each test flight.
   - At the center of the HUD is the flight ladder, which resembles a series of short bars that are arranged vertically in ascending order and distributed in increments of 2.5 degrees up to ±90°; the centermost bar (between ±5° range) is designated as 0° since it serves as the reference origin for the horizon. The flight ladder serves as the best reference for the pilot to quickly ascertain the orientation of the aircraft since its vertical alignment is fixed perpendicular to the horizon; the solid bars indicate a positive AOA or climbing, whereas the dashed bars indicate a negative AOA or descending. By knowing the pitching behavior of the airplane, the pilot can sense attitude deviations and can readily anticipate the necessary corrections to be made.
   - In the middle of the flight ladder is a circular airplane symbol, which represents the flight path of the airplane.
   - Just above the flight ladder is a row of small vertical marks representing the compass heading of the airplane. It is measured in 10's of degrees, ex. 06 indicates 60°, 21 indicates 210°, and so on. Therefore, the compass readings are: due north = 360°, due south = 180°, due east = 90°, and due west = 270°.
   - Located to the left of the flight ladder is a small rectangular box that displays the aircraft's indicated airspeed in units of knots. To the immediate right of the flight ladder is a second rectangular box that displays the aircraft's relative height above the SLS of the earth in units of ft.

   Key consideration #1: Even though the research conductor will remind the pilot when to continue with the next test point (in case the pilot becomes preoccupied) the pilot is still responsible for observing the clock parameter (the number appearing at the bottom of a cluster of discretes located on lower left corner of the HUD).



VISUALS

V: Continue close-up of the HUD monitor.

NARRATIVE INSTRUCTIONS

RCN: The mission profile for this flight lesson will address 3 basic flight maneuvers: level flight, climbing, and turning. To begin, the initial flight condition for any and all of the flight tests are automatically defaulted for level flight at an altitude of 10,000 ft., at a cruising airspeed of 90 kts., and on a due northerly heading, $\psi = 360°$. After the initial 18 sec. the autopilot is disengaged by the research conductor to allow the pilot full-control of the aircraft.
Note: Each flight will use either real-time audio cues or strip chart feedback. The audio cues are a series of beeps that will alert the pilot when they are "out-of-bounds", during flight. The strip chart will graphically show the pilot their entire performance during the post-flight evaluation.

7. *RCN:* The first flight lesson will be **LEVEL FLIGHT**.

- Key consideration #1: The aircraft flight model has an inherent "nose-down" tendency requiring the pilot to vigilantly maintain stick-control authority at all times. Additionally, adjustments in throttle setting will be frequent and must be carefully managed in order to maintain the required fixed airspeed.

- At time interval 0:19 to 0:50 >>> fly straight and level.

- Overview: Level flight is essentially a simple task requiring the pilot to maintain a consistent heading ($\psi = 360°$), altitude (10,000 ft.), and airspeed (90 kts.).

- The control inputs required for level flight are straightforward, since the pilot controls the altitude of the aircraft primarily through 2 input devices a) the control stick and b) throttle:
- a) In the case of maintaining level flight, the pilot is required to "rigidly" keep the stick as neutral or "centered" as possible, making only minor adjustments as the pitch varies.
- b) Likewise, the throttle also contributes to the AOA. By maintaining a consistent airspeed the desired altitude can be easily achieved and maintained.
- Since heading will not vary during level flight, the need for roll inputs is negated.
- Now, the HUD (more so than the instrument panel) will provide much of the visual flight information needed to determine level flight. The key parameters that must be observed are: i) airspeed, ii) the flight ladder, iii) altitude, and iv) time.

- Key consideration #2: For every action, there is an equal & opposite reaction: All stick inputs should be performed slowly, carefully, and deliberately so as to avoid excessive and undesired reactions during flight. The key to successfully performing any flight maneuver is to anticipate what control actions need to be done and knowing what corrections need to be made.

- Wrap-up Review: In order to maintain level flight, the pilot must:
    1. Use controlled stick inputs (primarily pitching) and make continuous throttle adjustments so as to achieve a stable AOA.
    2. Monitor the airspeed, flight ladder, and altitude HUD discretes so as to make the appropriate corrections & coordinated control inputs.

VISUALS

V-7A: Close-up of the instrument panel monitor.

Alternate between V-7A & 7B

V-7B: Close-up view of the HUD monitor.

Alternate between V-7A & 7B

V-8A & 8B: Same as 7A & 7B

V-9A: Close-up of instrument panel monitor.

V-10-A: Close-up of HUD monitor

NARRATIVE INSTRUCTIONS

8. *RCN:* The next flight lesson will focus on **CLIMBING**.

- At time interval 0:50 to 1:30 >>> climb at 1,000 ft/min to an altitude of 10,500 ft.

- Overview: Climbing simply requires the pilot to pull back on the control stick at a given AOA in order to achieve the desired altitude at the specified RoC, in this case 1000 ft./min.

9. *RCN:* To accomplish this, the pilot must now focus on the instrument panel monitor, specifically the ASI, ALI, and most importantly, the VSI. From the VSI, the pilot will be able to easily establish the desired RoC by gradually pulling back on the control stick to begin a shallow climb until the position-arrow on the VSI dial reaches the 1000 mark. Once completed, the pilot must maintain a fixed grip control of the control stick, in order to maintain the RoC, until the desired altitude is reached.

- Key consideration #1: The time allotted for achieving a given altitude at a specific RoC is the calculated rate required to do so.

- At time interval 1:30 to 2:00 >>> fly straight and level at 10,500 ft. altitude.

- Wrap-up Review: Positive pitching is the only required control input. By monitoring the VSI, ASI, and ALI, the pilot will have sufficient visual references to complete the task.

10. *RCN:* The last flight lesson to be covered is **TURNING**.

- At time interval 2:00 to 2:40 >>> perform a right level coordinated turn at 30° bank angle to change heading from 0° to 90°.

- Overview: the pilot is required to perform a series of horizontal turns at specified intervals in order to reach a specified heading.

11. *RCN:* To accomplish this, the pilot must perform a coordinated turn, as well as monitor the instrument panel for the ASI, AH, ALI, TC, and HI. The most important of these are the AH and TC. The AH is extremely helpful in providing the pilot with being aware of the pitching, banking, and turning behavior of the airplane. Similarly, the TC will provide complimentary information to assist the pilot in negotiating a coordinated turn.

- Key consideration #1: In order to perform a coordinated turn, the pilot will:
  1. Move the stick in the direction of the turn.
  2. Carefully pull back on the control stick until the desired heading is reached. At that point, the pilot will return the control stick to its neutral position.

  In our example we will make a turn to the right at a bank angle indicator arrow is approximately 30°, then gently pull back on the stick. This will allow the aircraft to perform a coordinated turn effortlessly, while keeping track of the desired heading and altitude.

- Wrap-up Review: The pilot will perform the coordinated turn using roll & pitch inputs, assisted by slight yawing inputs. Continue making minor adjustments in throttle setting to maintain the required airspeed.

- At time interval 2:40 to 3:19 >>> fly straight and level at 10,000 ft. altitude, and a 90° heading.

- CONCLUSION: This now concludes the orientation portion of the flight lesson. The next two lessons demonstrate level flight and climbing test flights.

NARRATIVE INSTRUCTIONS

VISUALS

V-1A (level): Close-up of the HUD monitor.

V-1A (climb): Alternate close-up of the instrument panel and HUD monitors.

Lesson # 1: Level Flight

- Key consideration #1: Positive adjustments in pitch will be the only required control inputs. Consistently monitor the airspeed, heading, flight ladder, altitude, and time parameters on the HUD.

- Overview: Level flight is essentially a simple task requiring the pilot to maintain a consistent heading ($\psi = 360°$), altitude (10,000 ft.), and airspeed (90 kts.).

1. *RCN:* Initial flight conditions are automatically commenced at a cruising airspeed of 90 kts., on a due Northerly heading ($\psi = 360°$), and at an altitude of 10,000 ft. After the initial 18 sec. the autopilot is disengaged to allow the subject full-control of the aircraft.
2. Take charge of the flight at 10,000 ft. altitude, heading toward N ($\psi = 360°$) at 90 kts. Maintain the same altitude, heading and airspeed for the complete duration of 180 seconds.

Time = 3:25 min.

- CONCLUSION: This now concludes the level flight lesson.

Lesson #2: Climb (Only)

- Key consideration #1: Positive adjustments in pitch will be the only required control inputs. Consistently monitor the VSI on the instrument panel during the climbing portions of the flight test. Otherwise, simply observe the airspeed, heading, flight ladder, altitude, and time parameters on the HUD.

- Overview: Climbing simply requires the pilot to pull back on the control stick at a given AOA in order to achieve the desired altitude at the specified RoC.

1. Take charge of the flight at 10,000 ft. altitude, on a northerly heading ($\psi = 360°$), and at an airspeed of 90 kts.
   - At time interval 0:19 to 0:43 >>> fly straight and level 10,000 ft. altitude 90 kts. airspeed.
   - At time interval 0:43 to 1:43 >>> climb at 500 ft/min up to an altitude of 10,500 ft. altitude.
   - At time interval 1:43 to 2:19 >>> fly straight and level at 10,500 ft. altitude 90 kts. airspeed.
   - At time interval 2:19 to 2:49 >>> climb at 1,000 ft/min up to an altitude of 11,000 ft.
   - At time interval 2:49 to 3:19 >>> fly straight and level at 11,000 ft. altitude and 90 kts. airspeed.

TOTAL TIME = 17:00 min.

- CONCLUSION: This now concludes the climbing lesson.

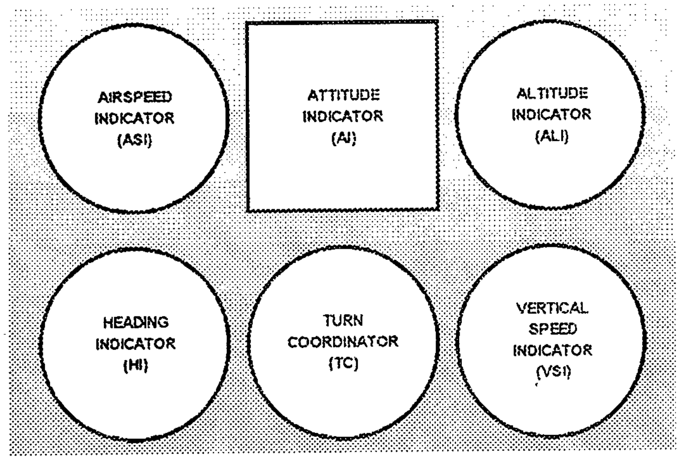
Time = 3:25 min.

SUPPLIMENT

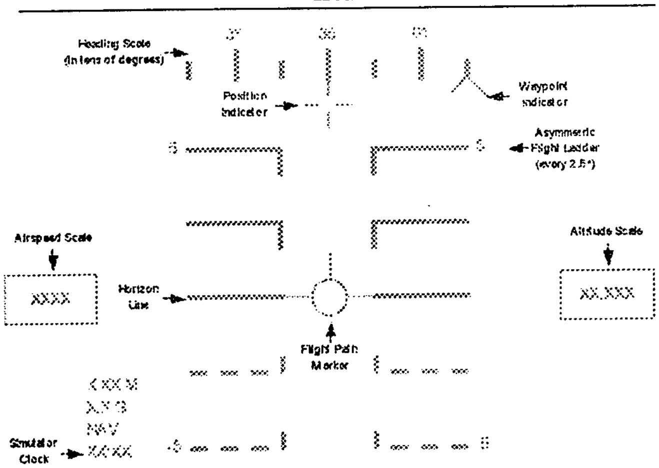
Flight Maneuver	Controllers			HUD					Instruments					
	Stick	Rudder	Throttle	Time	Airspeed	Flight Ladder	Heading	Altitude	ASI	AI	ALI	VSI	TC	HI
Level	Pitch		AOA	✓	✓	✓		✓						
Climb	Pitch		AOA	✓	✓	✓		✓	✓		✓	✓		
Turn	Roll	Yaw	AOA	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓

Table I: Controller, HUD, and Instrument Panel Cross-functionality Chart

Instrument Panel



HUD



APPENDIX II
GRADING OF FLIGHTS: INPUT FILES AND TYPICAL OUTPUT FILES

Appendix Table 1: Required parameter values and tolerances for 'A' grade in straight and level flight.

T (sec)	H (ft)	H_tol	H_dot (ft)	H_dot_tol	V (kts)	V_tol	Psi (deg)	Psi_tol
0	10000	50	0	100	90	3	0	2
3	10000	50	0	100	90	3	0	2
6	10000	50	0	100	90	3	0	2
9	10000	50	0	100	90	3	0	2
12	10000	50	0	100	90	3	0	2
15	10000	50	0	100	90	3	0	2
18	10000	50	0	100	90	3	0	2
21	10000	50	0	100	90	3	0	2
24	10000	50	0	100	90	3	0	2
27	10000	50	0	100	90	3	0	2
30	10000	50	0	100	90	3	0	2
33	10000	50	0	100	90	3	0	2
36	10000	50	0	100	90	3	0	2
39	10000	50	0	100	90	3	0	2
42	10000	50	0	100	90	3	0	2
45	10000	50	0	100	90	3	0	2
48	10000	50	0	100	90	3	0	2
51	10000	50	0	100	90	3	0	2
54	10000	50	0	100	90	3	0	2
57	10000	50	0	100	90	3	0	2
60	10000	50	0	100	90	3	0	2
63	10000	50	0	100	90	3	0	2
66	10000	50	0	100	90	3	0	2
69	10000	50	0	100	90	3	0	2
72	10000	50	0	100	90	3	0	2
75	10000	50	0	100	90	3	0	2
78	10000	50	0	100	90	3	0	2
81	10000	50	0	100	90	3	0	2
84	10000	50	0	100	90	3	0	2
87	10000	50	0	100	90	3	0	2
90	10000	50	0	100	90	3	0	2
93	10000	50	0	100	90	3	0	2
96	10000	50	0	100	90	3	0	2
99	10000	50	0	100	90	3	0	2
102	10000	50	0	100	90	3	0	2
105	10000	50	0	100	90	3	0	2
108	10000	50	0	100	90	3	0	2
111	10000	50	0	100	90	3	0	2
114	10000	50	0	100	90	3	0	2
117	10000	50	0	100	90	3	0	2
120	10000	50	0	100	90	3	0	2
123	10000	50	0	100	90	3	0	2
126	10000	50	0	100	90	3	0	2
129	10000	50	0	100	90	3	0	2
132	10000	50	0	100	90	3	0	2
135	10000	50	0	100	90	3	0	2
138	10000	50	0	100	90	3	0	2
141	10000	50	0	100	90	3	0	2
144	10000	50	0	100	90	3	0	2
147	10000	50	0	100	90	3	0	2
150	10000	50	0	100	90	3	0	2
153	10000	50	0	100	90	3	0	2
156	10000	50	0	100	90	3	0	2
159	10000	50	0	100	90	3	0	2
162	10000	50	0	100	90	3	0	2
165	10000	50	0	100	90	3	0	2
168	10000	50	0	100	90	3	0	2
171	10000	50	0	100	90	3	0	2
174	10000	50	0	100	90	3	0	2
177	10000	50	0	100	90	3	0	2
180	10000	50	0	100	90	3	0	2

Appendix Table 2: Required parameter values and tolerances for 'A' grade in climbing flight. (Input file)

t (sec)	H (ft)	H_tol	H_dot (ft)	H_dot_tol	V (kts)	V_tol	Psi (deg)	Psi_tol
0	10000	50	ng		ng		ng	
6	10000	50	ng		ng		ng	
12	10000	50	ng		ng		ng	
18	10000	50	ng		ng		ng	
24	10000	50	ng		ng		ng	
30	ng		ng		ng		ng	
33	ng		500	100	ng		0	3
36	ng		500	100	ng		0	3
39	ng		500	100	ng		0	3
42	ng		500	100	ng		0	3
45	ng		500	100	ng		0	3
48	ng		500	100	ng		0	3
51	ng		500	100	ng		0	3
54	ng		500	100	ng		0	3
57	ng		500	100	ng		0	3
60	ng		500	100	ng		0	3
63	ng		500	100	ng		0	3
66	ng		500	100	ng		0	3
69	ng		500	100	ng		0	3
72	ng		500	100	ng		0	3
75	ng		500	100	ng		0	3
78	ng		500	100	ng		0	3
81	ng		500	100	ng		0	3
84	ng		500	100	ng		0	3
90	ng		ng		ng		ng	
96	10500	50	ng		ng		ng	
102	10500	50	ng		ng		ng	
108	10500	50	ng		ng		ng	
114	10500	50	ng		ng		ng	
120	ng		ng		ng		ng	
123	ng		1000	100	ng		0	3
126	ng		1000	100	ng		0	3
129	ng		1000	100	ng		0	3
132	ng		1000	100	ng		0	3
135	ng		1000	100	ng		0	3
138	ng		1000	100	ng		0	3
141	ng		1000	100	ng		0	3
144	ng		1000	100	ng		0	3
150	ng		ng		ng		ng	
156	11000	50	ng		ng		ng	
162	11000	50	ng		ng		ng	
168	11000	50	ng		ng		ng	
174	11000	50	ng		ng		ng	
180	11000	50	ng		ng		ng	

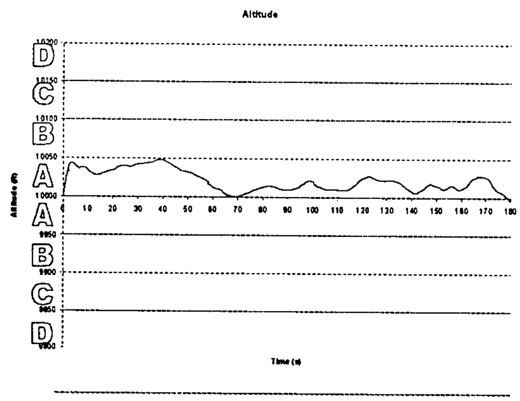
Appendix Table 3: Required parameter values and tolerances for 'A' grade in level turn flight. (Input file)

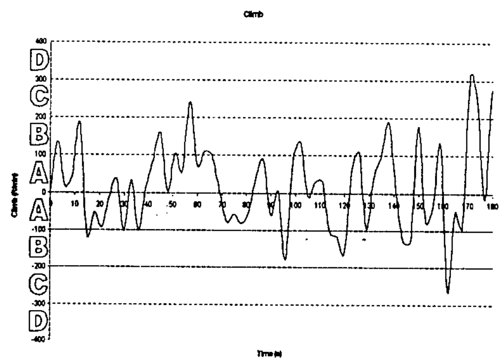
t (sec)	H (ft)	H_tol	H_dot (ft)	H_dot_tol	V (kts)	V_tol	Psi (deg)	Psi_tol	phi (deg)	phi_tol
0	10000	50			90	3	0	2	ng	ng
6	10000	50			90	3	0	2	ng	ng
12	10000	50			90	3	0	2	ng	ng
18	10000	50			90	3	0	2	ng	ng
21	ng				ng	ng	ng	ng	ng	ng
24	10000	50			90	3	ng	ng	30	3
27	10000	50			90	3	ng	ng	30	3
30	10000	50			90	3	ng	ng	30	3
33	10000	50			90	3	ng	ng	30	3
36	10000	50			90	3	ng	ng	30	3
39	10000	50			90	3	ng	ng	30	3
42	10000	50			90	3	ng	ng	30	3
45	10000	50			90	3	ng	ng	30	3
48	10000	50			90	3	ng	ng	30	3
51	10000	50			90	3	ng	ng	30	3
54	10000	50			90	3	ng	ng	30	3
57	10000	50			90	3	ng	ng	30	3
60	10000	50			90	3	ng	ng	30	3
63	10000	50			90	3	ng	ng	30	3
66	10000	50			90	3	ng	ng	30	3
69	10000	50			90	3	ng	ng	30	3
72	10000	50			90	3	ng	ng	30	3
75	ng				ng	ng	ng	ng	ng	ng
81	10000	50			90	3	180	2	ng	ng
87	10000	50			90	3	180	2	ng	ng
93	10000	50			90	3	180	2	ng	ng
99	10000	50			90	3	180	2	ng	ng
105	10000	50			90	3	180	2	ng	ng
111	10000	50			90	3	180	2	ng	ng
117	ng				ng	ng	ng	ng	ng	ng
120	10000	50			90	3	ng	ng	45	3
123	10000	50			90	3	ng	ng	45	3
126	10000	50			90	3	ng	ng	45	3
129	10000	50			90	3	ng	ng	45	3
132	10000	50			90	3	ng	ng	45	3
135	10000	50			90	3	ng	ng	45	3
138	10000	50			90	3	ng	ng	45	3
141	10000	50			90	3	ng	ng	45	3
144	10000	50			90	3	ng	ng	45	3
147	10000	50			90	3	ng	ng	45	3
150	10000	50			90	3	ng	ng	45	3
153	10000	50			90	3	ng	ng	45	3
156	10000	50			90	3	ng	ng	45	3
159	10000	50			90	3	ng	ng	45	3
162	10000	50			90	3	ng	ng	45	3
165	10000	50			90	3	ng	ng	45	3
168	10000	50			90	3	ng	ng	45	3
171	ng				ng	ng	ng	ng	ng	ng
174	10000	50			90	3	0	2	ng	ng
177	10000	50			90	3	0	2	ng	ng
180	10000	50			90	3	0	2	ng	ng

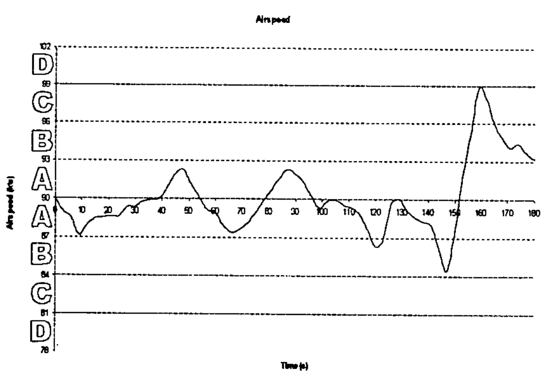
Appendix Table 4: Test 1 Input Scoring Sheet

t (sec)	H (ft)	H_tol	H_dot (ft)	H_dot_tol	V (kts)	V_tol	Psi (deg)	Psi_tol	phi (deg)	phi_tol
0	10000	50	ng	ng	90	3	0	2	ng	ng
3	10000	50	ng	ng	90	3	0	2	ng	ng
6	10000	50	ng	ng	90	3	0	2	ng	ng
9	10000	50	ng	ng	90	3	0	2	ng	ng
12	10000	50	ng	ng	90	3	0	2	ng	ng
15	10000	50	ng	ng	90	3	0	2	ng	ng
18	ng	ng	ng	ng	ng	ng	ng	ng	ng	ng
21	ng	ng	1000	100	90	3	0	2	ng	ng
24	ng	ng	1000	100	90	3	0	2	ng	ng
27	ng	ng	1000	100	90	3	0	2	ng	ng
30	ng	ng	1000	100	90	3	0	2	ng	ng
33	ng	ng	1000	100	90	3	0	2	ng	ng
36	ng	ng	1000	100	90	3	0	2	ng	ng
39	ng	ng	1000	100	90	3	0	2	ng	ng
42	ng	ng	1000	100	90	3	0	2	ng	ng
45	ng	ng	1000	100	90	3	0	2	ng	ng
48	ng	ng	ng	ng	ng	ng	ng	ng	ng	ng
51	10500	50	ng	ng	90	3	0	2	ng	ng
54	10500	50	ng	ng	90	3	0	2	ng	ng
57	10500	50	ng	ng	90	3	0	2	ng	ng
60	10500	50	ng	ng	90	3	0	2	ng	ng
63	ng	ng	ng	ng	ng	ng	ng	ng	ng	ng
66	ng	ng	-500	100	90	3	0	2	ng	ng
69	ng	ng	-500	100	90	3	0	2	ng	ng
72	ng	ng	-500	100	90	3	0	2	ng	ng
75	ng	ng	-500	100	90	3	0	2	ng	ng
78	ng	ng	-500	100	90	3	0	2	ng	ng
81	ng	ng	-500	100	90	3	0	2	ng	ng
84	ng	ng	-500	100	90	3	0	2	ng	ng
87	ng	ng	-500	100	90	3	0	2	ng	ng
90	ng	ng	-500	100	90	3	0	2	ng	ng
93	ng	ng	-500	100	90	3	0	2	ng	ng
96	ng	ng	-500	100	90	3	0	2	ng	ng
99	ng	ng	-500	100	90	3	0	2	ng	ng
102	ng	ng	-500	100	90	3	0	2	ng	ng
105	ng	ng	-500	100	90	3	0	2	ng	ng
108	ng	ng	-500	100	90	3	0	2	ng	ng
111	ng	ng	-500	100	90	3	0	2	ng	ng
114	ng	ng	-500	100	90	3	0	2	ng	ng
117	ng	ng	-500	100	90	3	0	2	ng	ng
120	ng	ng	-500	100	90	3	0	2	ng	ng
123	ng	ng	ng	ng	ng	ng	ng	ng	ng	ng
126	10000	50	ng	ng	90	3	0	2	ng	ng
129	10000	50	ng	ng	90	3	0	2	ng	ng
132	10000	50	ng	ng	90	3	0	2	ng	ng
135	10000	50	ng	ng	90	3	0	2	ng	ng
138	10000	50	ng	ng	90	3	0	2	ng	ng
141	ng	ng	ng	ng	ng	ng	ng	ng	ng	ng
144	10000	50	ng	ng	90	3	ng	ng	30	3
147	10000	50	ng	ng	90	3	ng	ng	30	3
150	10000	50	ng	ng	90	3	ng	ng	30	3
153	10000	50	ng	ng	90	3	ng	ng	30	3
156	10000	50	ng	ng	90	3	ng	ng	30	3
159	10000	50	ng	ng	90	3	ng	ng	30	3
162	10000	50	ng	ng	90	3	ng	ng	30	3
165	10000	50	ng	ng	90	3	ng	ng	30	3
168	ng	ng	ng	ng	ng	ng	ng	ng	ng	ng
171	10000	50	ng	ng	90	3	90	2	ng	ng
174	10000	50	ng	ng	90	3	90	2	ng	ng
177	10000	50	ng	ng	90	3	90	2	ng	ng
180	10000	50	ng	ng	90	3	90	2	ng	ng

Chart 1: Strip Charts For Straight and Level







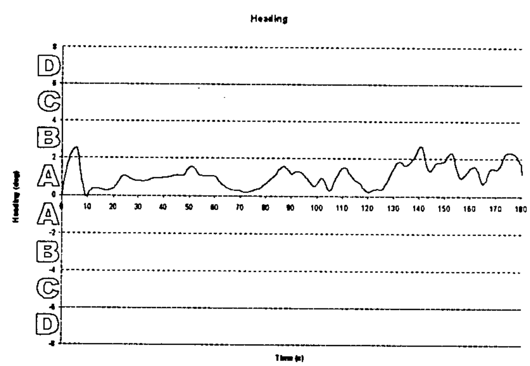
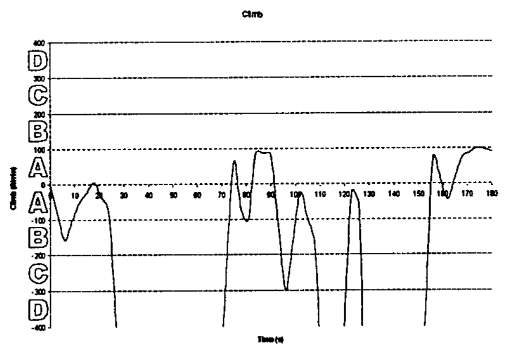
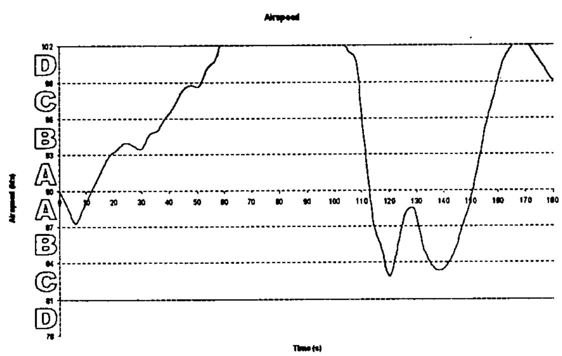
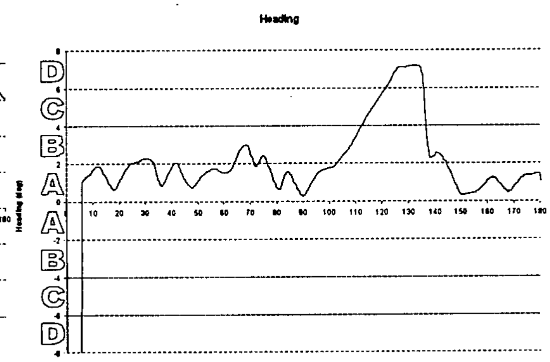


Chart 2: Strip Charts for Climbing







Appendix Table 5: Output grading file for Straight and Level flight, determined from the computer's scoring system.

Time increment (sec)	ALTITUDE value for given time extrapolated from previous data	CLIMB value for given time extrapolated from previous data	AIRSPEED value for given time extrapolated from previous data	Corrected HEADING
0	10000	0	90	0
3	10042.90478	133.4549797	88.99247146	1.972088253
6	10036.95224	17.42969652	88.51970395	2.43417659
9	10037.09723	45.21561511	87.1502833	-0.001764923
12	10029.03347	183.4861453	87.96132151	0.346810598
15	10028.52351	-113.9001126	88.46305635	0.312255747
18	10032.52253	-51.57366256	88.52831851	0.24841622
21	10035.6818	-92.06978968	88.63499934	0.469155247
24	10040.26427	-12.25242809	88.60999058	1.041729638
27	10038.44517	36.66926522	89.37542296	0.845405912
30	10041.94034	-101.6426377	89.38536956	0.778844055
33	10042.94976	34.88581786	89.75492955	0.774407308
36	10044.85145	-100.6177643	89.89870207	0.895763931
39	10047.81064	12.30707829	89.98764826	0.917577605
42	10044.46596	83.49679681	90.83447075	0.963292385
45	10038.29004	158.4178688	91.91855971	1.075180524
48	10033.64659	4.360854498	92.25752355	1.070299878
51	10031.44739	103.8682815	91.15485159	1.568658282
54	10026.93917	57.78109217	90.10810989	1.08441991
57	10022.32253	241.2788818	89.14721134	1.065458161
60	10012.76792	72.42235696	88.87568126	1.021877593
63	10009.03652	110.5392788	87.9312087	0.54710453
66	10002.36966	97.47931269	87.36435256	0.310942861
69	10000.33655	9.675568538	87.60664256	0.277196623
72	10002.52047	-77.01068042	88.0965718	0.162053973
75	10006.6987	-55.80859452	88.8666792	0.261450151
78	10009.87255	-81.46575897	89.85037741	0.4070436
81	10014.0791	-50.84379715	90.68074127	0.741195489
84	10014.28698	42.6245659	91.62364552	1.102568858
87	10010.46748	86.62199703	92.31012987	1.578671941
90	10009.33387	-57.27446613	91.94186778	1.184061858
93	10011.15331	3.860489485	91.30556664	1.286723209
96	10016.68777	-178.5763788	90.2003606	0.954762856
99	10021.44919	88.06651116	89.32538991	0.476091984
102	10014.59399	135.758796	89.85563102	0.932884936
105	10010.51542	-7.237316961	89.90904333	0.26431865
108	10010.79381	29.98906529	89.54469169	1.048450001
111	10009.55833	31.73483171	89.33528338	1.53292574
114	10009.7421	-104.3013432	88.82661992	0.96395472
117	10015.81796	-116.8954544	87.72329602	0.633346557
120	10024.46475	-161.5640396	86.32607966	0.199094328
123	10027.43708	60.44882916	86.84731006	0.359369841
126	10023.14261	106.9053922	89.63928069	0.389593837
129	10022.18771	-93.6990439	90.02297754	1.101203393
132	10022.58627	42.97699595	89.14038281	1.804373692
135	10019.33113	98.96088693	88.56687575	1.616234812
138	10012.22394	187.5328496	88.29091418	1.974957708
141	10006.35973	10.19286291	88.0185389	2.642629879
144	10009.67335	-130.320417	86.31591412	1.341598253
147	10017.5202	-128.4874809	84.46672494	1.757735163
150	10015.38074	176.9218556	87.27819291	1.831085469
153	10010.88196	-74.3241179	91.75450822	2.281009869
156	10016.35805	-37.26357861	95.08021466	0.97348902
159	10010.72293	128.9409953	98.78531932	1.273748688
162	10015.23034	-263.5090932	97.94433608	1.56686633
165	10025.23856	-47.82502255	96.00520673	0.645639321
168	10027.9171	-90.48032135	94.86303492	1.42210558
171	10024.73858	309.8611014	94.08056613	1.447400826
174	10010.42427	241.8633668	94.40005011	2.230023737
177	10005.46718	-14.24938328	93.63892088	2.259867418
180	9996.815098	274.5311635	93.22517771	1.552141525

Appendix Table 6: Output grading file with letter grades available, determined from computer's scoring system for Straight and Level flight.

Time increment (sec)	ALTITUDE Grade (number)	ALTITUDE Grade (letter)	CLIMB Grade (number)	CLIMB Grade (letter)	AIRSPEED Grade (number)	AIRSPEED Grade (letter)	HEADING Grade (number)	HEADING Grade (letter)
0	4	A	4	A	4	A	4	A
3	4	A	3	B	4	A	3	B
6	4	A	4	A	4	A	2	C
9	4	A	4	A	4	A	0	E
12	4	A	3	B	4	A	0	E
15	4	A	3	B	4	A	0	E
18	4	A	4	A	4	A	0	E
21	4	A	4	A	4	A	0	E
24	4	A	4	A	4	A	0	E
27	4	A	4	A	4	A	0	E
30	4	A	3	B	4	A	0	E
33	4	A	4	A	4	A	0	E
36	4	A	3	B	4	A	0	E
39	4	A	4	A	4	A	0	E
42	4	A	4	A	4	A	0	E
45	4	A	3	B	4	A	0	E
48	4	A	4	A	4	A	0	E
51	4	A	3	B	4	A	0	E
54	4	A	4	A	4	A	0	E
57	4	A	2	C	4	A	0	E
60	4	A	4	A	4	A	0	E
63	4	A	3	B	4	A	0	E
66	4	A	4	A	4	A	0	E
69	4	A	4	A	4	A	0	E
72	4	A	4	A	4	A	0	E
75	4	A	4	A	4	A	0	E
78	4	A	4	A	4	A	0	E
81	4	A	4	A	4	A	0	E
84	4	A	4	A	4	A	0	E
87	4	A	4	A	4	A	0	E
90	4	A	4	A	4	A	0	E
93	4	A	4	A	4	A	0	E
96	4	A	3	B	4	A	0	E
99	4	A	4	A	4	A	0	E
102	4	A	3	B	4	A	0	E
105	4	A	4	A	4	A	0	E
108	4	A	4	A	4	A	0	E
111	4	A	4	A	4	A	0	E
114	4	A	3	B	4	A	0	E
117	4	A	3	B	4	A	0	E
120	4	A	3	B	3	B	0	E
123	4	A	4	A	3	B	0	E
126	4	A	3	B	4	A	0	E
129	4	A	4	A	4	A	0	E
132	4	A	4	A	4	A	0	E
135	4	A	4	A	4	A	0	E
138	4	A	3	B	4	A	0	E
141	4	A	4	A	4	A	0	E
144	4	A	3	B	3	B	0	E
147	4	A	3	B	3	B	0	E
150	4	A	3	B	4	A	0	E
153	4	A	4	A	4	A	0	E
156	4	A	4	A	3	B	0	E
159	4	A	3	B	2	C	0	E
162	4	A	2	C	2	C	0	E
165	4	A	4	A	2	C	0	E
168	4	A	4	A	3	B	0	E
171	4	A	1	D	3	B	0	E
174	4	A	2	C	3	B	0	E
177	4	A	4	A	3	B	0	E
180	4	A	2	C	3	B	0	E

Appendix Table 7: GPA Averages for Altitude, Climb, Airspeed, and Heading during Straight and Level flight.

				Altitude		Climb	
Grade Averages:	First 30 seconds (0-30)			4.00	A	3.63	B
	Second 30 seconds (30-60)			4.00	A	3.73	B
	Third 30 seconds (60-90)			4.00	A	3.60	B
	Fourth 30 seconds (90-120)			4.00	A	3.07	B
	Fifth 30 seconds (120-150)			4.00	A	1.33	D
	Last 30 seconds (150-180)			4.00	A	1.29	D
	Overall			**4.00**	**A**	**3.51**	**B**

				Airspeed		Heading	
Grade Averages:	First 30 seconds (0-30)			4.00	A	3.96	B
	Second 30 seconds (30-60)			4.00	A	4.00	A
	Third 30 seconds (60-90)			3.87	B	4.00	A
	Fourth 30 seconds (90-120)			3.07	B	3.73	B
	Fifth 30 seconds (120-150)			3.00	B	0.38	E
	Last 30 seconds (150-180)			3.00	B	0.27	E
	Overall			**3.74**	**B**	**3.93**	**B**

APPENDIX III

PARAMETERS FOR FLIGHT MANEUVERS

BY JOSEPH L. VOGEL

Written for the Air Force study on developing a system of scoring aircraft training maneuvers.

The following parameters address the four basic flight training maneuvers that underlie all of the conditions of flight that can be encountered. By training each candidate to flawlessly accomplish each of these basic maneuvers, the flight instructor can then help the trainee combine them into more complex maneuvers that one needs to know to become an accomplished and safe pilot.

The four basic maneuvers in question are: Climbs, descents, turns, and straight and level flight. straight and level flight is described as a series of minute climbs. descents, and turns to maintain a line through the sky. More complex maneuvers such as climbing and descending turns, constant rate maneuvers, constant speed maneuvers and other complex tasks are simply combinations of the four basic maneuvers. Using these parameters, the scoring and post mission critique will be oriented toward self instruction by using low cost systems. Parameters are taken from FAA-S-8081d4, PRIVATE PILOT PRACTICAL TEST STANDARDS FOR AIRPLANE dated Max' 1995. Additionally, parameters are taken from several of the flight training publications such as AC 61-21, FLIGHT TRAINING HANDBOOK, and AC 61-23, PILOT'S HANDBOOK OF AERONAUTICAL KNOWLEDGE and the AIM (Airman's Information Manual.) Reference was also made to commercially available publications and from the personal flight instructing experience of the writer.

For each maneuver, the trainee must begin to establish the parameters within 5 seconds to score a 4. If any parameter is exceeded, trainee will re-establish the proper parameter or will establish a positive remedial trend toward the correct value within 5 seconds to score a 4.

At this writing, the maneuver is initiated and completed when the instructor announces it and signals start and stop times to the computer. However, if it proves to be desirable, the start time may be established by a computer prompt, thereby also starting the timing sequence. The maneuver will be considered established after two consecutive two second computer samples agree that the parameters are being met. Time of establishment of the maneuver will be retroactive to start time of the first sample. Scores will be determined after the maneuver is completed by comparing the trainee's performance of the maneuver to a "template" of the maneuver stored in the computer database.

Criteria for establishing parameters for all maneuvers:
Establish parameters or establish positive remedial trend:

within 5 seconds	Score 4
within 6 seconds	Score 3
within 7 seconds	Score 2
within 8 seconds	Score 1
9 seconds or more	Score 0

Aircraft State variables: Rate changes = the summation of the rate change throughout the maneuver. This will give an indication of the trainee's ability to smoothly control the aircraft throughout the maneuver. Control inputs may be another data set to look at. Large control inputs at low speeds may not result in large excursions from optimum but are considered poor technique.

During each maneuver, the computer sampling rate will be once every two seconds.

THE CLIMB (CONSTANT AIRSPEED)

Parameters for the climb: Based on a Cessna 172 aircraft. Target Airspeed 70kts

1. Trainee will establish Vy (Best rate of climb) airspeed within plus or minus 10 knots.
   a. Plus 5, minus 5 knots — Score 4
   b. Plus 6, minus 6 knots — Score 3
   c. Plus 8, minus 8 knots — Score 2
   d. Plus 10, minus 10 knots — Score 1
   e. Outside of parameters — Score 0 (If out more than 8 seconds and not trending back to optimum)
   f. Trending back to optimum within 8 seconds, Score 1

2. Trainee will maintain given heading plus or minus 20 degrees.
   a. Plus 5, minus 5 degrees — Score 4
   b. Plus 10, minus 10 degrees — Score 3
   c. Plus 15, minus 15 degrees — Score 2
   d. Plus 20 minus 20 degrees — Score 1
   e. Outside parameters — Score 0 (If out more than 8 seconds and not trending back to optimum)
   f. Trending back to optimum within 8 seconds, Score 1

3. Once airspeed is established, trainee will maintain established pitch attitude plus or minus 8 degrees.
   a. Plus 3, minus 3 degrees — Score 4
   b. Plus 5, minus 5 degrees — Score 3
   c. Plus 7, minus 7 degrees — Score 2
   d. Plus 8, minus 8 degrees — Score 1
   e. Outside parameters — Score 0 (If out more than 8 seconds and not trending back to optimum)
   f. Trending back to optimum within 8 seconds, Score 1

4. Once airspeed is established, trainee will not vary vertical speed by more than plus or minus 500 feet per minute (FPM).
   a. Plus 80, minus 80 FPM — Score 4
   b. Plus 200, minus 200 FPM — Score 3
   c. Plus 300, minus 300 FPM — Score 2
   d. Plus 500, minus 500 FPM — Score 1
   e. Over 500 FPM — Score 0 (If out more than 8 seconds and not trending back to optimum.)
   f. Trending back to optimum within 8 seconds, Score 1)

5. Level off will be at assigned plus or minus 200 feet. Once established at that altitude, trainee will maintain that altitude plus or minius 200 feet for 30 seconds.
   a. Plus 100 minus 100 feet — Score 4
   b. Plus 150 minus 150 feet — Score 3
   c. Plus 100 minus 100 feet — Score 2
   d. Plus 50 minus 50 feet — Score 1
   e. More than 200 feet — Score 0 (if out more than 8 seconds and not trending back to optimum)
   f. Trending back to optimum within 8 seconds, Score 1

6. If any parameter is exceeded, trainee will re-establish the proper parameter or will establish a positive remedial trend toward the correct value within 8 seconds.

THE DESCENT (POWER OFF)

(Constant airspeed descent: Target airspeed 70 knots)
Parameters for the descent based on a Cessna 172 aircraft

Trainee will reduce power to idle, hold the aircraft level and establish the best glide airspeed then establish the proper glide angle to maintain that airspeed. Target airspeed is 70 knots.

1. Once airspeed is established, trainee will maintain that airspeed, plus or minus 10 knots.

   a. Plus 5, minus 5 knots — Score 4
   b. Plus 6, minus 6 knots — Score 3
   c. Plus 8 minus 8 knots — Score 2
   d. Plus 10, minus 10 knots — Score 1
   e. Outside parameters — Score 0 (If out more than 8 seconds and not trending back to optimum)
   f. Trending back to optimum within 8 seconds, Score 1

2. Once airspeed is established, trainee will maintain established pitch attitude plus or minus 10 degrees.

   a. Plus 5, minus 5 degrees — Score 4
   b. Plus 6 minus 6 degrees — Score 3
   c. Plus 8, minus 8 degrees — Score 2
   d. Plus 10, minus 10 degrees — Score 1
   e. Outside parameters — Score 0 (If out more than 8 seconds and not trending back to optimum)
   f. Trending back to optimum within 8 seconds, Score 1

3. Trainee will maintain given heading plus or minus 20 degrees.

   a. Plus 8, minus 8 degrees — Score 4
   b. Plus 10, minus 10 degrees — Score 3
   c. Plus 15, minus 15 degrees — Score 2
   d. Plus 20, minus 20 degrees — Score 1
   e. Outside parameters — Score 0 (If out more than 8 seconds and not trending back to optimum.)
   f. Trending back to optimum within 8 seconds, Score 1.

4. Once airspeed is established, trainee will not vary vertical speed by more than plus or minus 500 feet per minute (FPM).

   a. Plus 80, minus 80 FPM — Score 4
   b. Plus 200, minus 200 FPM — Score 3
   c. Plus 300, minus 300 FPM — Score 2
   d. Plus 400, minus 400 FPM — Score 1
   e. Over 500 FPM — Score 0 (If out more than 8 seconds and not trending back to optimum)
   f. Trending back to optimum within 8 seconds, Score 1.

5. Level off will be at assigned altitude plus or minus 200 feet. Once established at that trainee will maintain that altitude plus or minus 200 feet for 30 seconds.

   a. Plus 100 minus 100 feet — Score 4
   b. Plus 150 minus 150 feet — Score 3
   c. Plus 100 minus 100 feet — Score 2
   d. Plus 50 minus 50 feet — Score 1
   e. More than 200 feet — Score 0 (If out more than 8 seconds and not trending back to optimum)
   f. Trending back to optimum within 8 seconds, Score 1.

6. If any parameter is exceeded, trainee will re-establish the proper parameter within 8 seconds or will establish a positive remedial trend toward the correct value.

TURNS TO HEADINGS

Parameters for the maneuver based on a Cessna 172 aircraft
(Target airspeed 100 knots)

1. Trainee will establish an angle of bank for a medium banked turn. A medium banked turn is defined as one in which the bank angle is maintained at 20 degrees. Ideal rate of turn is 1.5 degrees per second.

   a. Plus 5, minus 5 degrees — Score 4
   b. Plus 7, minus 7 degrees — Score 3
   c. Plus 9, minus 9 degrees — Score 2

d. Plus 8, minus 8 degrees Score 1
e. Over plus or minus 8 degrees bank Score 0 (If out more than 8 seconds and not trending back to optimum)
f. Trending back to optimum within 8 seconds, Score 1.

2. Once bank is established, trainee will maintain altitude within plus or minus 200 feet.
   a. Plus 50, minus 50 feet Score 4
   b. Plus 80, minus 80 feet Score 3
   c. Plus 150, minus 150 feet Score 2
   d. Plus 200, minus 200 feet Score 1
   e. Outside parameters Score 0 (If out more than 8 seconds and not trending back to optimum.)
   f. Trending back to optimum within 8 seconds, Score 1.

3. Trainee will maintain cruise airspeed within plus or minus 10 knots.
   a. Plus 3, minus 3 knots Score 4
   b. Plus 7, minus 7 knots Score 3
   c. Plus 9, minus 9 knots Score 2
   d. Plus 8, minus 8 knots Score 1
   e. Outside of parameters Score 0 (If out more than 8 seconds and not trending back to optimum.)
   f. Trending back to optimum within 8 seconds, Score 1.

4. Trainee will roll out of turn on assigned heading plus or minus 20 degrees. Trainee will hold that heading for 30 seconds.
   a. Plus 5, minus 5 degrees Score 4
   b. Plus 8 minus 8 degrees Score 3
   c. Plus 15, minus 15 degrees Score 2
   d. Plus 20, minus 20 degrees Score 1
   e. Outside of parameters Score 0 (If out more than 8 seconds and not trending back to optimum.)
   f. Trending back to optimum within 8 seconds, Score 1.

STRAIGHT AND LEVEL FLIGHT

Parameters for the maneuver based on a Cessna 172 aircraft
(Target cruise airspeed, 100 knots)

1. Once altitude is established, trainee will maintain altitude within plus or minus 200 feet.
   a. Plus 50, minus 50 feet Score 4
   b. Plus 80, minus 80 feet Score 3
   c. Plus 150, minus 150 feet Score 2
   d. Plus 200, minus 200 feet Score 1
   e. Outside parameters Score 0 (If out more than 8 seconds and not trending back to optimum.)
   f. Trending back to optimum within 8 seconds, Score 1.

2. Trainee will maintain given heading plus or minus 20 degrees.
   a. Plus 5, minus 5 degrees Score 4
   b. Plus 8, minus 8 degrees Score 3
   c. Plus 15, minus 15 degrees Score 2
   d. Plus 20 minus 20 degrees Score 1
   e. Outside parameters Score 0 (If out more than 8 seconds and not trending back to optimum)
   f. Trending back to optimum within 8 seconds, Score 1.

3. Trainee will establish cruise airspeed of 100 knots. Cruise airspeed will be maintained within plus or minus 10 knots.
   a. Plus 5, minus 5 knots Score 4
   b. Plus 6, minus 6 knots Score 3
   c. Plus 8, minus 8 knots Score 2
   d. Plus 10, minus 10 knots Score 1

e. Outside of parameters Score 0 (If out more than 8 seconds and not trending back to optimum.
f. Trending back to optimum within 8 seconds, Score 1.

4. Once airspeed, altitude and heading is established, trainee will not vary vertical speed by more than plus or minus 500 feet per minute (FPM).
   a. Plus 100, minus 100 FPM Score 4
   b. Plus 200, minus 200 FPM Score 3
   c. Plus 300, minus 300 FPM Score 2
   d. Plus 400, minus 400 FPM Score 1
   e. Over 500 FPM Score 0 (If out more than 8 seconds and not trending back to optimum)
   f. Trending back to optimum within 8 seconds, Score 1.

CONSTANT AIRSPEED CLIMBING TURN

Parameters for the climb: Based on a Cessna 172 aircraft. Target Airspeed 70 knots

For this maneuver, trainee will simultaneously establish climb and bank attitude to maintain a constant airspeed, constant turn rate climbing turn.

1. Trainee will establish V_y (Best rate of climb) airspeed within plus or minus 10 knots.
   a. Plus 5, minus 5 knots Score 4
   b. Plus 6, minus 6 knots Score 3
   c. Plus 8, minus 8 knots Score 2
   d. Plus 10, minus 10 knots Score 1
   e. Outside of parameters Score 0 (If out more than 8 seconds and not trending back to optimum)
   f. Trending back to optimum within 8 seconds, Score 1.

2. Trainee will establish an angle of bank for a medium banked turn. A medium banked turn is defined as one in which the bank angle is maintained at 20 degrees.
   a. Plus 5, minus 5 degrees Score 4
   b. Plus 10, minus 10 degrees Score 3
   c. Plus 15, minus 15 degrees Score 2
   d. Plus 20 minus 20 degrees Score 1
   e. Outside parameters Score 0 (If out more than 8 seconds and not trending back to optimum)
   f. Trending back to optimum within 8 seconds, Score 1

3. Ideal turn rate is 1.5 degrees per second.
   a. Plus 5, minus 5 degrees Score 4
   b. Plus 7, minus 7 degrees Score 3
   c. Plus 9, minus 9 degrees Score 2
   d. Plus 8, minus 8 degrees Score 1
   e. Over plus or minus 8 deg bank Score 0 (If out more than 8 seconds and not trending back to optimum)
   f. Trending back to optimum within 8 seconds, Score 1.

4. Once airspeed is established, trainee will not vary vertical speed by more than plus or minus 500 feet per minute (FPM).
   a. Plus 80, minus 80 FPM Score 4
   b. Plus 200, minus 200 FPM Score 3
   c. Plus 300, minus 300 FPM Score 2
   d. Plus 500, minus 500 FPM Score 1
   e. Over 500 FPM Score 0 (If out more than 8 seconds and not trending back to optimum.)
   f. Trending back to optimum within 8 seconds, Score 1.

5. Trainee will roll out of turn on assigned heading plus or minus 20 degrees. Trainee will hold that heading for 30 seconds.
   a. Plus 5, minus 5 degrees Score 4

b. Plus 8 minus 8 degrees Score 3
c. Plus 15, minus 15 degrees Score 2
d. Plus 20, minus 20 degrees Score 1
e. Outside of parameters Score 0 (If out more than 8 seconds and not trending back to optimum.)
f. Trending back to optimum within 8 seconds, Score 1.

NOTE: Assigned level off altitude will normally be 500 feet above the altitude the maneuver was started.

6. Level off will be at assigned altitude plus or minus 200 feet. Once established at that altitude, trainee will maintain that altitude plus or minus 200 feet for 30 seconds.
   a. Plus 100 minus 100 feet Score 4
   b. Plus 150 minus 150 feet Score 3
   c. Plus 100 minus 100 feet Score 2
   d. Plus 50 minus 50 feet Score 1
   e. More than 200 feet Score 0 (If out more than 8 seconds and not trending back to optimum)
   f. Trending back to optimum within 8 seconds, Score 1

CONSTANT AIRSPEED DESCENDING TURN

(Constant airspeed descent: Target airspeed 70 knots)
Parameters for the descent based on a Cessna 172 aircraft

Trainee will reduce power to idle, hold the aircraft level and establish the best glide airspeed then simultaneously establish the proper glide and bank angle to maintain that airspeed and rate of turn. Target airspeed is 70 knots. Rate of turn target is 2 degrees per second.

1. Once airspeed is established, trainee will maintain that airspeed, plus or minus 10 knots.
   a. Plus 5, minus 5 knots Score 4
   b. Plus 6, minus 6 knots Score 3
   c. Plus 8 minus 8 knots Score 2
   d. Plus 10, minus 10 knots Score 1
   e. Outside parameters Score 0 (If out more than 8 seconds and not trending back to optimum)
   f. Trending back to optimum within 8 seconds, Score 1.

2. Trainee will establish an angle of bank for a medium banked turn. A medium banked turn is defined as one in which the bank angle is maintained at 20 degrees.
   a. Plus 5, minus 5 degrees Score 4
   b. Plus 7, minus 7 degrees Score 3
   c. Plus 9, minus 9 degrees Score 2
   d. Plus 8, minus 8 degrees Score 1
   e. Over plus or minus 8 deg bank Score 0 (If out more than 8seconds and not trending back to optimum)
   f. Trending back to optimum within 8 seconds, Score 1.

3. Once airspeed and bank angle is established, trainee will not vary vertical speed by more than plus or minus 500 feet per minute (FPM).
   a. Plus 80, minus 80 FPM Score 4
   b. Plus 200, minus 200 FPM Score 3
   c. Plus 300, minus 300 FPM Score 2
   d. Plus 400, minus 400 FPM Score 1
   e. Over 500 FPM Score 0 (If out more than 8 seconds and not trending back to optimum)
   f. Trending back to optimum within 8 seconds, Score 1.

4. Level off will be at assigned altitude plus or minus 200 feet. Once established at that trainee will maintain that altitude plus or minus 200 feet for 30 seconds.

a. Plus 100 minus 100 feet Score 4
b. Plus 150 minus 150 feet Score 3
c. Plus 100 minus 100 feet Score 2
d. Plus 50 minus 50 feet Score 1
e. More than 200 feet Score 0 (If out more than 8 seconds and not trending back to optimum)
f. Trending back to optimum within 8 seconds, Score 1.

5. Trainee will roll out of turn on assigned heading plus or minus 20 degrees. Trainee will hold that heading for 30 seconds.
a. Plus 5, minus 5 degrees Score 4
b. Plus 8 minus 8 degrees Score 3
c. Plus 15, minus 15 degrees Score 2
d. Plus 20, minus 20 degrees Score 1
e. Outside of parameters Score 0 (If out more than 8 seconds and not trending back to optimum.)
f. Trending back to optimum within 8 seconds, Score 1.

6. If any parameter is exceeded, trainee will re-establish the proper parameter within 8 seconds or will establish a positive remedial trend toward the correct value.

THE CLIMB (CONSTANT RATE OF CLIMB)

Parameters for the climb: Based on a Cessna 172 aircraft. Target Airspeed 70 knots, target rate of climb, 500 feet per minute

1. Trainee will establish V_y (Best rate of climb) airspeed within plus or minus 10 knots.
a. Plus 5, minus 5 knots Score 4
b. Plus 6, minus 6 knots Score 3
c. lus 8, minus 8 knots Score 2
d. Plus 10, minus 10 knots Score 1
e. Outside of parameters Score 0 (If out more than 8 seconds and not trending back to optimum)
f. Trending back to optimum within 8 seconds, Score 1.

2. Trainee will maintain given heading plus or minus 20 degrees.
a. Plus 5, minus 5 degrees Score 4
b. Plus 10, minus 10 degrees Score 3
c. Plus 15, minus 15 degrees Score 2
d. Plus 20 minus 20 degrees Score 1
e. Outside parameters Score 0 (If out more than seconds and not trending back to optimum)
f. Trending back to optimum within 8 seconds, Score 1

3. Once airspeed is established, trainee will maintain established pitch attitude to hold 500 feet per minute rate of climb plus or minus 8 degrees.
a. Plus 3, minus 3 degrees Score 4
b. Plus 5, minus 5 degrees Score 3
c. Plus 7, minus 7 degrees Score 2
d. Plus 8, minus 8 degrees Score 1
e. Outside parameters Score 0 (If out more than seconds and not trending back to optimum)
f. Trending back to optimum within 8 seconds, Score 1.

4. Once airspeed is established, trainee will maintain vertical speed and not vary by more than plus or minus 200 feet per minute.
a. Plus 50, minus 50 FPM Score 4
b. Plus 100, minus 100 FPM Score 3
c. Plus 150, minus 150 FPM Score 2
d. Plus 200, minus 200 FPM Score 1
e. Over 200 FPM Score 0 (If out more than 8 seconds and not trending back to optimum.)
f. Trending back to optimum within 8 seconds, Score 1.

5. Level off will be at assigned altitude plus or minus 200 feet. Once established at that trainee will maintain that altitude plus or minus 200 feet for 30 seconds.

a. Plus 100 minus 100 feet Score 4
b. Plus 150 minus 150 feet Score 3
c. Plus 100 minus 100 feet Score 2
d. Plus 50 minus 50 feet Score 1
e. More than 200 feet Score 0 (If out more than 8 seconds and not trending back to optimum)
f. Trending back to optimum within 8 seconds, Score 1.

6. If any parameter is exceeded, trainee will re-establish the proper parameter or will establish a positive remedial trend toward the correct value within 8 seconds.

CONSTANT RATE OF CLIMB - CLIMBING TURN

Parameters for the climb: Based on a Cessna 172 aircraft. Target Airspeed 70 knots, target rate of climb, 500 feet per minute.

For this maneuver, trainee will simultaneously increase power and establish climb and bank attitude to maintain a constant airspeed, constant turn rate and constant rate of climb climbing turn. Power setting will vary as needed.

1. Trainee will establish V_y (Best rate of climb) airspeed within plus or minus 10 knots.
   a. Plus 5, minus 5 knots Score 4
   b. Plus 6, minus 6 knots Score 3
   c. Plus 8, minus 8 knots Score 2
   d. Plus 10, minus 10 knots Score 1
   e. Outside of parameters Score 0 (If out more than 8 seconds and not trending back to optimum)
   f. Trending back to optimum within 8 seconds, Score 1

2. Trainee will establish an angle of bank for a medium banked turn. A medium banked turn is defined as one in which the bank angle is maintained at 20 degrees.
   a. Plus 5, minus 5 degrees Score 4
   b. Plus 10, minus 10 degrees Score 3
   c. Plus 15, minus 15 degrees Score 2
   d. Plus 20 minus 20 degrees Score 1
   e. Outside parameters Score 0 (If out more than 8 seconds and not trending back to optimum)
   f. Trending back to optimum within 8 seconds, Score 1

3. Ideal turn rate is 1.5 degrees per second.
   a. Plus 5, minus 5 degrees Score 4
   b. Plus 7, minus 7 degrees Score 3
   c. Plus 9, minus 9 degrees Score 2
   d. Plus 8, minus 8 degrees Score 1
   e. Over plus or minus 8 deg bank Score 0 (If out more than 8 seconds and not trending back to optimum)
   f. Trending back to optimum within 8 seconds, Score 1.

4. Once airspeed is established, trainee will maintain established pitch attitude to hold 500 feet per minute rate of climb plus or minus 8 degrees.
   a. Plus 3, minus 3 degrees Score 4
   b. Pius 5, minus 5 degrees Score 3
   c. Plus 7, minus 7 degrees Score 2
   d. Plus 8, minus 8 degrees Score 1
   e. Outside parameters Score 0 (If out more than 8 seconds and not trending back to optimum)
   f. Trending back to optimum within 8 seconds, Score 1

5. Once airspeed is established, trainee will maintain vertical speed and not vary by more than plus or minus 200 feet per minute.
   a. Plus 50, minus 50 FPM   Score 4
   b. Plus 100, minus 100 FPM   Score 3
   c. Plus 150, minus 150 FPM   Score 2
   d. Plus 200, minus 200 FPM   Score 1
   e. Over 200 FPM   Score 0 (If out more than 8 seconds and not trending back to optimum.)
   f. Trending back to optimum within 8 seconds, Score 1.

6. Trainee will roll out of turn on assigned heading plus or minus 20 degrees. Trainee will hold that heading for 30 seconds.
   a. Plus 5, minus 5 degrees   Score 4
   b. Plus 8 minus 8 degrees   Score 3
   c. Plus 15, minus 15 degrees   Score 2
   d. Plus 20, minus 20 degrees   Score 1
   e. Outside of parameters   Score 0 (If out more than 8 seconds and not trending back to optimum.)
   f. Trending back to optimum within 8 seconds, Score 1.

NOTE: Assigned level off altitude will normally be 500 feet above the altitude the maneuver was started.

7. Level off will be at assigned altitude plus or minus 200 feet. Once established at that altitude, trainee will maintain that altitude plus or minus 200 feet for 30 seconds.
   a. Plus 100 minus 100 feet   Score 4
   b. Plus 150 minus 150 feet   Score 3
   c. Plus 100 minus 100 feet   Score 2
   d. Plus 50 minus 50 feet   Score 1
   e. More than 200 feet   Score 0 (If out more than 8 seconds and not trending back to optimum)
   f. Trending back to optimum within 8 seconds, Score 1.

CONSTANT AIRSPEED, CONSTANT RATE OF DESCENT

Target airspeed 70 knots, target rate of descent, 500 feet per minute
Parameters for the descent based on a Cessna 172 aircraft

Trainee will reduce power, hold the aircraft level and establish the target glide airspeed and target rate of descent then establish the proper glide angle and power setting to maintain those targets.

1. Once airspeed is established, trainee will maintain that airspeed, plus or minus 10 knots.
   a. Plus 5, minus 5 knots   Score 4
   b. Plus 6, minus 6 knots   Score 3
   c. Plus 8 minus 8 knots   Score 2
   d. Plus 10, minus 10 knots   Score 1
   a. Outside parameters   Score 0 (If out more than 8 seconds and not trending back to optimum)
   b. Trending back to optimum within 8 seconds, Score 1

2. Once airspeed and rate of descent is established, trainee will maintain established pitch attitude plus or minus 10 degrees.
   a. Plus 5, minus 5 degrees   Score 4
   b. Plus 6 minus 6 degrees   Score 3
   c. Plus 8, minus 8 degrees   Score 2
   d. Plus 10, minus 10 degrees   Score 1
   e. Outside parameters   Score 0 (If out more than 8 seconds and not trending back to optimum)
   f. Trending back to optimum within 8 seconds, Score 1

3. Once airspeed is established, trainee will maintain vertical speed and not vary bv more than plus or minus 200 feet per minute. (FPM).
   a. Plus 50, minus 50 FPM — Score 4
   b. Plus 100, minus 100 FPM — Score 3
   c. Plus 150, minus 150 FPM — Score 2
   d. Plus 200, minus 200 FPM — Score 1
   e. Over 200 FPM — Score 0 (If out more than 8 seconds and not trending back to optimum.)
   f. Trending back to optimum within 8 seconds, Score 1.

4. Level off will be at assigned altitude plus or minus 200 feet. Once established at that trainee will maintain that altitude plus or minus 200 feet for 30 seconds.
   a. Plus 100 minus 100 feet — Score 4
   b. Plus 150 minus 150 feet — Score 3
   c. Plus 100 minus 100 feet — Score 2
   d. Plus 50 minus 50 feet — Score 1
   e. More than 200 feet — Score 0 (If out more than 8 seconds and not trending back to optimum)
   f. Trending back to optimum within 8 seconds, Score 1.

5. If any parameter is exceeded, trainee will re-establish the proper parameter within 8 seconds or will establish a positive remedial trend toward the correct value.

CONSTANT RATE OF DESCENT - CONSTANT AIRSPEED DESCENDING TURN

(Target airspeed 70 knots, target rate of descent: 500 feet per minute)
Parameters for the descent based on a Cessna 172 aircraft

Trainee will reduce power, hold the aircraft level and establish the target airspeed then establish the proper glide angle and power setting to maintain airspeed and rate of descent simultaneously. Target airspeed is 70 knots, target rate of descent is 500 feet per minute. Target rate of turn is one and one-half degrees per second.

1. Once airspeed is established, trainee will maintain that airspeed, plus or minus 10 knots.
   a. Plus 5, minus 5 knots — Score 4
   b. Plus 6, minus 6 knots — Score 3
   c. Plus 8 minus 8 knots — Score 2
   d. Plus 10, minus 10 knots — Score 1.
   e. Outside parameters — Score 0 (If out more than 8 seconds and not trending back to optimum)
   f. Trending back to optimum within 8 seconds, Score 1.

2. Once airspeed is established, trainee will maintain established pitch attitude plus or minus 10 degrees.
   a. Plus 5, minus 5 degrees — Score 4
   b. Plus 6 minus 6 degrees — Score 3
   c. Plus 8, minus 8 degrees — Score 2
   d. Plus 10, minus 10 degrees — Score 1
   e. Outside parameters seconds — Score 0 (If out more than 8 and not trending back to optimum)
   f. Trending back to optimum within 8 seconds, Score 1.

3. Once airspeed is established, trainee will maintain vertical speed and not vary by more than plus or minus 200 feet per minute.
   a. Plus 50, minus 50 FPM — Score 4
   b. Plus 100, minus 100 FPM — Score 3
   c. Plus 150, minus 150 FPM — Score 2
   d. Plus 200, minus 200 FPM — Score 1
   e. Over 200 FPM — Score 0 (If out more than 8 seconds and not trending back to optimum.)
   f. Trending back to optimum within 8 seconds, Score 1.

4. Level off will be at assigned altitude plus or minus 200 feet. Once established at that trainee will maintain that altitude plus or minus 200 feet for 30 seconds.
   a. Plus 100 minus 100 feet   Score 4
   b. Plus 150 minus 150 feet   Score 3
   c. Plus 100 minus 100 feet   Score 2
   d. Plus 50 minus 50 feet   Score 1
   e. More than 200 feet   Score 0 (If out more than 8 seconds and not trending back to optimum)
   f. Trending back to optimum within 8 seconds, Score 1.

5. Trainee will roll out of turn on assigned heading plus or minus 20 degrees. Trainee will hold that heading for 30 seconds.
   a. Plus 5, minus 5 degrees   Score 4
   b. Plus 8 minus 8 degrees   Score 3
   c. Plus 15, minus 15 degrees   Score 2
   d. Plus 20, minus 20 degrees   Score 1
   e. Outside of parameters   Score 0 (If out more than 8 seconds and not trending back to optimum.)
   f. Trending back to optimum within 8 seconds, Score 1.

6. If any parameter is exceeded, trainee will re-establish the proper parameter within 8 seconds or will establish a positive remedial trend toward the correct value.

APPENDIX IV
SIMULTANEOUS GRADING OF SOME FLIGHTS
BY COMPUTER AND BY INSTRUCTOR

The following terms are from the evaluation of the simulator from a qualified instructor.

Student = student number
ip = the performance score assigned by the human instructor pilot.
sw = the performance score assigned by the software (automated scoring system).
Sample = observations 1 through 6 for each flight.
Maneuver = the flight maneuver attempted:
1 = straight & level;
2 = turn;
3 = climb.
Task = the flight task that was scored:
10=altitude;
11=airspeed;
12=heading;
13=heading & bank angle;
14=all.

Appendix Table 8: Instructors Evaluation

student	ip	sw	sample	maneuver	task
3	3	3	1	1	10
3	3	3	2	1	10
3	3	3.9	3	1	10
3	4	3	4	.1	10
3	4	4	5	1	10
3	4	3.6	6	1	10
4	1	4	1	1	10
4	1	4	2	1	10
4	1	4	3	1	10
4	1	4	4	1	10
4	2	4	5	1	10
4	2	4	6	1	10
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6	2	2.4	6	1	10
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7	2	0	3	1	10
7	3	1.8	4	1	10
7	3	3.8	5	1	10
7	4	4	6	1	10
3	4	3.8	1	1	11
3	3	3.7	2	1	11
3	4	4	3	1	11
3	4	3.8	4	1	11
3	4	4	5	1	11
3	4	4	6	1	11
4	1	0	1	1	11
4	1	0	2	1	11
4	1	0	3	1	11
4	1	0.8	4	1	11
4	1	0.6	5	1	11
4	1	0	6	1	11
5	3	3.8	1	1	11
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6	1	2	5	1	11
6	1	1.6	6	1	11
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3	4	4	4	1	12
3	4	4	5	1	12
3	4	4	6	1	12
4	3	2.3	1	1	12
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4	1	2.6	6	1	12
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6	4	3.8	6	1	12
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1	2	0.7	3	1	14
1	2	0.6	4	1	14
1	2	1	5	1	14
1	2	0.9	6	1	14
3	4	3.8	1	1	14
3	4	3.9	2	1	14
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3	4	4	4	1	14
3	4	4	5	1	14
3	4	4	6	1	14
4	3	2.9	1	1	14
4	2	2.6	2	1	14
4	3	2.9	3	1	14
4	2	2.2	4	1	14
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5	2	3.3	1	1	14
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5	4	4	4	1	14
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5	4	4	6	1	14

student	ip	sw	sample	maneuver	task
6	3	3.4	1	1	14
6	4	3	2	1	14
6	4	3.2	3	1	14
6	3	3.7	4	1	14
6	3	2.9	5	1	14
6	3	3.1	6	1	14
7	2	2.5	1	1	14
7	2	1.8	2	1	14
7	3	2.6	3	1	14
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7	3	2.5	5	1	14
7	2	2	6	1	14
1	3	2.7	1	2	13
1	2	3	2	2	13
3	3	3	1	2	13
3	3	3.3	2	2	13
3	3	1.7	3	2	13
3	2	3.4	4	2	13
3	2	2.1	5	2	13
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5	4	3	5	2	13
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7	4	3.2	1	2	13
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7	4	1.6	4	2	13
7	3	1.8	5	2	13
7	3	0.2	6	2	13
3	4	4	1	2	10
3	3	2.8	2	2	10
3	1	1.3	3	2	10
3	3	3.5	4	2	10
3	2.3	1.4	5	2	10
4	3	2.7	1	2	10

student	ip	sw	sample	maneuver	task
4	2	2.5	2	2	10
4	2	3	3	2	10
4	2	1.9	4	2	10
4	3	0.9	5	2	10
4	2	0.4	6	2	10
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1	2	3.4	2	3	14
1	2	3.1	3	3	14
1	2	4	4	3	14
3	4	3.5	1	3	14
3	2	0.5	2	3	14
3	2	2.4	3	3	14
3	3	0.6	4	3	14
3	2	0	5	3	14
3	2	1.2	6	3	14
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4	2	1.4	2	3	14
4	3	2.8	3	3	14
4	2	0	4	3	14
4	1	0	5	3	14
4	1	2.2	6	3	14
5	4	3.8	1	3	14
5	4	2.3	2	3	14
5	4	3.6	3	3	14
5	4	3.2	4	3	14
5	4	0.9	5	3	14
5	4	2.8	6	3	14
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6	2	1.9	3	3	14
6	2	3.2	4	3	14
6	2	2.4	5	3	14
6	2	3	6	3	14
7	4	3.5	1	3	14
7	3	3	2	3	14
7	4	1.9	3	3	14
7	3	3	4	3	14
7	3	1.6	5	3	14
7	3	2.4	6	3	14

APPENDIX V
ADDITIONAL DATA

Appendix Table 9: Scoring Results for RTWF

Student #	1	4	7	10	15	16	19
flight code	1	1	1	1	1	1	1
GPA							
L1	0.869	1.332	3.475	2.750	1.135	2.426	2.066
L2	2.475	0.492	3.467	3.635	1.193	2.262	1.545
L3	3.332	0.840	3.791	3.664	1.201	1.971	2.123
L4	3.475	1.102	3.787	3.525	1.672	1.889	2.020
C1	1.284	1.433	2.224	1.672	0.597	0.925	1.522
C2	2.209	0.224	2.254	1.940	1.776	0.761	1.194
T1	1.409	0.877	1.149	1.688	0.922	0.799	0.942
T2	1.104	0.753	1.591	1.260	0.656	0.968	0.422
L5	3.492	1.574	3.795	3.549	0.930	1.434	2.463
L6	3.463	1.939	3.795	3.725	1.918	2.082	2.357
L7	3.578	2.180	3.898	3.725	1.770	2.791	2.131
L8	3.779	1.197	3.910	3.779	1.975	2.914	2.697
L9							
L10							
C3	2.358	1.642	2.284	2.254	1.328	1.597	1.970
C4	2.119	1.925	2.194	2.388	2.000	2.119	1.925
C5							0.000
T3	1.519	0.539	1.286	1.675	0.461	1.149	1.019
T4	1.623	0.299	1.494	1.974	0.831	1.104	0.266
T5							0.000
Test1	1.691	0.800	1.388	2.242	0.739	1.964	1.182
Test2	2.036	1.273	1.430	2.152	0.321	1.861	1.479

L = Straight and Level
C = Climbs
T =Turns

Appendix Table 10: Scoring Results for RTWOF

Student #	2	5	8	12	14	17	20
flight code	2	2	2	2	2	2	2
GPA							
L1	2.639	2.443	0.975	3.016	1.611	0.730	1.160
L2	3.656	3.074	0.594	3.680	1.398	0.525	0.807
L3	3.332	3.426	1.918	3.803	2.254	0.512	1.840
L4	3.582	3.475	1.926	3.799	2.471	1.066	2.459
C1	1.701	1.537	1.418	2.313	0.940	0.433	1.313
C2	2.239	2.000	0.776	2.104	1.806	0.299	1.343
T1	0.948	1.006	1.357	0.870	0.799	0.584	0.610
T2	1.481	0.968	0.604	1.162	1.149	0.240	0.455
L5	3.541	3.561	2.037	3.590	2.570	0.566	2.488
L6	3.648	3.570	2.205	3.525	2.779	1.066	0.861
L7	3.619	3.652	2.291	3.627	2.951	0.967	1.779
L8	3.541	3.705	2.123	3.791	3.041	0.676	1.971
L9							
L10							
C3	2.209	1.910	1.075	1.552	1.597	0.701	0.716
C4	2.388	1.955	1.328	1.970	1.955	1.284	1.269
C5							
T3	1.753	0.812	0.734	1.727	0.708	0.519	1.208
T4	1.890	0.766	0.786	1.721	0.532	0.370	0.532
T5							
Test1	1.861	1.606	1.285	1.406	1.539	0.800	1.545
Test2	1.897	1.382	0.648	1.430	1.315	0.709	1.612

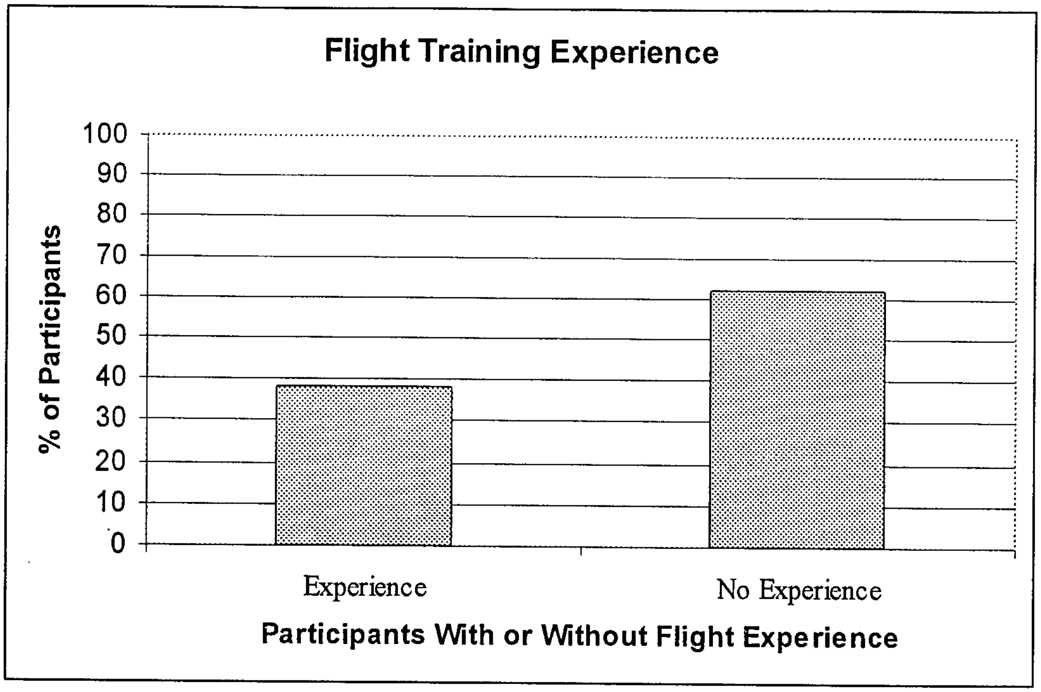
L = Straight and Level
C = Climbs
T =Turns

Appendix Table 11: Scoring Results for RT/ARTWF

Student #	3	6	9	11	13	18	21
flight code	1&2	1&2	1&2	1&2	1&2	1&2	1&2
GPA							
L1	0.803	0.947	1.172	3.336	2.570	0.525	2.451
L2	1.643	1.299	1.246	3.057	3.725	1.516	3.443
L3	1.135	2.254	1.795	3.094	3.631	1.660	3.701
L4	0.230	2.234	1.418	3.365	3.766	2.258	3.803
C1	0.642	0.284	1.254	1.836	1.896	1.358	1.194
C2	0.597	1.134	0.642	1.627	2.224	0.104	1.896
T1	0.883	0.682	0.688	0.903	2.104	0.273	1.331
T2	0.857	0.981	1.182	0.857	2.039	0.864	1.318
L5	0.635	1.115	1.057	3.217	2.816	1.914	3.541
L6	2.340	0.980	1.537	3.201	3.238	2.873	3.324
L7	2.857	1.930	1.467	3.184	3.615	1.176	3.648
L8	1.275	0.557	1.914	3.496	3.348	1.492	3.270
L9	1.594	1.680	2.807	3.504	3.025	1.967	3.537
L10	0.631	0.959	1.975	3.016	3.660	1.881	3.639
C3	0.313	1.075	0.955	2.045	2.299	1.299	1.642
C4	0.403	1.299	1.522	2.090	2.209	1.821	1.881
C5	0.881	1.343	0.881	2.164	2.254	0.881	1.866
T3	0.675	0.604	0.753	1.422	1.370	0.773	1.110
T4	0.604	0.604	0.922	0.942	2.110	0.812	1.136
T5	0.474	0.688	0.864	1.468	1.721	0.870	0.948
Test1	0.424	0.879	0.461	2.176	2.170	1.424	1.552
Test2	1.030	0.642	0.509	1.448	2.127	1.333	1.770

L = Straight and Level
C =Climb
T =Turns

Percentage of Participants With or Without Flight Experience

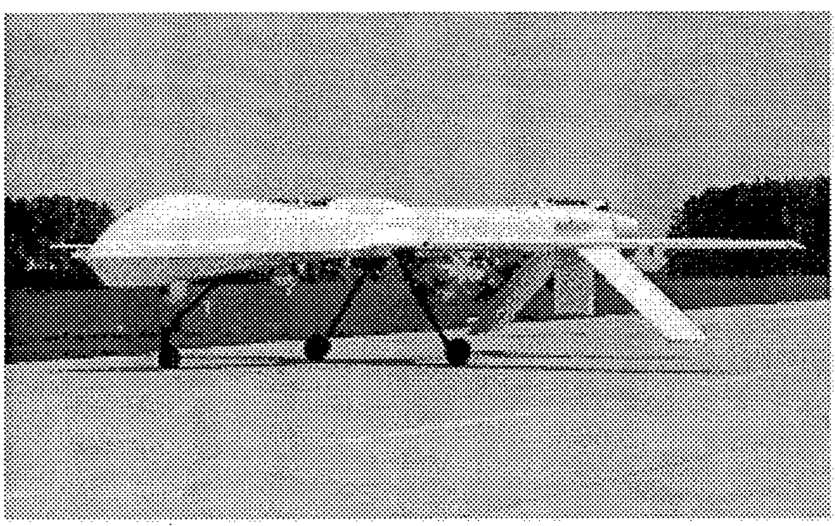


Based on the twenty-one participants.

A full operational system consisting of four air vehicles with sensors, a ground controls station, a TROJAN SPIRIT II SATCOM communication suite, and 55 personal.

Primary Function: Airborne Surveillance Reconnaissance and Target Acquisition
Contractor: General Atomics Aeronautical Systems Incorporated
Power Plant: Rotax 912 4-cylinder engine, producing 81 horsepower
Weight: 2250
Length: 27 feet
Height: 6.9 feet
Wing Area: 263 ft^2
Wingspan: 48.7 feet
Speed: 80 to 120 knots
Range: up to 400 nm
Ceiling: up to 25,000 feet
Fuel Capacity: 665 pounds (100 gallons)
Payload: 450 pounds
Aspect Ratio: 9
$C_{m\alpha}$ = -0.45
C_{mq} = -10.0
Moments of inertia
I_{xx} = 2500
I_{yy} = 11500
I_{zz} = 8000

Adopted from Predator 1999



Picture 2: RQ-1A Predator UAV at Edwards AFB